Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://archive.org/details/proceedingsofin421932indi

PROCEEDINGS

OF THE

Forty-eighth Annual Meeting

Indiana Academy of Science

FOUNDED DECEMBER 29, 1885

VOLUME 42

Stanley A. Cain, Editor

Held at University of Notre Dame
South Bend, Indiana
November 17-19, 1932

Copies of the Proceedings may be purchased through the editor at $3.00 per volume

---

INDIANAPOLIS:
WM. B. BURFORD PRINTING CO., CONTRACTOR FOR STATE PRINTING AND BINDING
1933

TABLE OF CONTENTS

Page

Officers and Committees for 1932 5
Minutes of the Spring Meeting 6
Minutes of the Winter Meeting 6

Memorials

Barton Warren Evermann, by W. S. Blatchley 11
Carl Leo Mees, by D. B. Prentice 15
David R. Moore, by Amos Butler 18
Eugene Daniel O'Connell, by Daniel Hull 19

Papers on Bacteriology

Electrode Potentials and Poorly Poised Biological Systems, by W. P. Allyn, Terre Haute 21
Evaluation of Antiseptics by Test Tube Methods, by H. M. Powell and W. A. Jamieson, Lilly Research Laboratories .. 27
The Influence of Antiseptics on Phagocytosis, by H. M. Powell and W. A. Jamieson, Lilly Research Laboratories 32
The Use of Germ-Free Guinea Pigs in Bacteriology, by J. Arthur Reyniers, Notre Dame 35
The Mechanization of Certain Bacteriological Procedures, by J. Arthur Reyniers, Notre Dame 37
The Isolation of Anaerobic Cellulose-Decomposing Bacteria from Various Sources, by W. L. Weis, Purdue 41

Papers on Botany

Some Algae of the Lower Wabash Valley, by M. E. Britton and B. H. Smith, Indiana State Teachers College 45
Plants New or Rare to Indiana, XVIII, by Chas. C. Deam, Bluffton 47
Measurement of Plant Growth by Means of Optical Levers, by Raymond E. Girton, Purdue 51
Some Effects of Lightning on Tomato Plants, by Stacy Hawkins, Florida Agriculture Experiment Station 57
The Development and Structure of the Juvenile Leaves in *Marsilea quadrifolia* with Notes on the Anatomy of the Stem and Adult Petiole, by Ruth V. Henderson, Indiana ... 61
Pollen Statistics for Two Indiana Bogs, by Paul King Houdek, Robinson, Illinois 73
Some Algae of Vigo, Greene and Daviess Counties, by Louise M. Love and Robert L. Rogers, Indiana State Teachers College 79
The Types of Linnaean Genera, by J. A. Nieuwland, Notre Dame 83
The Distribution of the Alga, Lemanea, in Indiana, by C. Mervin Palmer, Butler 89

Page

Algae of Indiana: Second List of Additions to the 1875-1928 Check List, by C. Mervin Palmer, Butler 90
Notes on Indiana Grasses, 1932, by J. E. Potzger, Butler 93
A Field Study of the Common Barberry, by Winona H. Welch, DePauw 97
DePauw University Arboretum, by Winona H. Welch, DePauw 99

Papers on Chemistry

Vapor Phase Esterification, by Frank E. Dolian and H. T. Briscoe, Indiana 101
Studies in Etherification, by G. F. Hennion, H. D. Hinton and J. A. Nieuwland, Notre Dame 109
The Action of Energizers During Case-Carburization, by E. G. Mahin and J. A. Toussaint, Notre Dame 113
The Action of Vanadium Oxytrichloride upon Various Organic Compounds, by R. E. Nelson and A. H. McFadden, Purdue .. 119
Chlorine in the Lead Storage Battery, by R. L. Shelley and O. W. Brown, Indiana 123
Boron Fluoride in Acetal Catalysis, by Thomas H. Vaughn, Notre Dame 127
The Catalytic Synthesis of Glycol Acetal, by Thomas H. Vaughn and J. A. Nieuwland, Notre Dame 131

Papers on Geology and Geography

Some Hills of Circumalluviation in the Lower Wabash Valley, by Marion M. Fidlar, Indiana 135
Geologic Structure of the Unionville Gas Field, Monroe County, Indiana, by Richard Freed, Indiana 141
Geological and Structural Conditions in the Union Oil and Gas Field, by William N. Logan, Indiana 149
The Physiographic Features of Pine Hills Nature Study Park, Montgomery County, Indiana, by Ernest Rice Smith, DePauw 153

Papers on Physics

Permalloy Filings for Mapping Magnetic Fields, by Arthur L. Foley, Indiana 163
Audio Frequency Transformer Impedance, by J. B. Hershman, Indiana 165
The Design and Use of a Photoelectric Photometer, by B. A. Howlett, Rose Polytechnic Institute 177
The Effect of Spacing and Area of Absorber on the Absorption of Acoustical Materials, by James F. Mackell, Indiana 181
Theoretical and Practical Screen Grid Amplification, by William A. Parker, Indiana 195
A Vacuum Tube Tuning Fork Drive, Using Forks of Several Different Frequencies, by Harold D. Webb, Indiana 199

Papers on Zoology Page
A List of the Coccidae of Tippecanoe County and Their Hosts (Homoptera), by John M. Amos, Purdue 205
Descriptions of Coccidae Heretofore Unreported from Indiana (Homoptera), by John M. Amos, Purdue 208
Insects of Indiana for 1932, by J. J. Davis, Purdue 213
The Cicadellinae of Indiana (Cicadellidae, Homoptera), by Howard O. Deay, Purdue 227
Some Anatomical Features of the Tiger Snail, *Anguispira alternata* (Say), by David T. Jones, Indiana 243
Some Observations on the Reproductive Cycle of the Infusorian, *Ichthyophthirius multifiliis*, by Nathan E. Pearson, Butler .. 251
A New Medium for Drosophila Cultures, by S. A. Rifenburgh, Purdue 257
Fresh-Water Medusae at Terre Haute, Indiana, by W. P. Allyn and L. J. Rettger, Indiana State Teachers College 259
The Masking of Sepia by White, Two Recessive Eye-Colors in Drosophila, by Floyd T. Romberger, Jr., Purdue 261
Birds of Tippecanoe County, III, by Louis A. Test and Frederick H. Test, Purdue 269

Members elected since the publication of volume 41 287
Junior Academy of Science Clubs elected since the publication of volume 41 288

OFFICERS AND COMMITTEES FOR 1932[1]

President, FERNANDUS PAYNE, Indiana University, Bloomington.
Vice-President, RICHARD LIEBER, Department of Conservation, Indianapolis.
Secretary, RAY C. FRIESNER, Butler University, Indianapolis.
Treasurer, MARCUS W. LYON, JR., 214 LaPorte Ave., South Bend.
Press Secretary, W. E. EDINGTON, DePauw University, Greencastle.
Editor, STANLEY A. CAIN, Indiana University, Bloomington.
Trustees of the Academy Foundation, FRANK B. WADE (Term expires 1935), Shortridge High School, Indianapolis; JOHN S. WRIGHT, (Term expires 1936), Eli Lilly & Co., Indianapolis; MARCUS W. LYON, JR., Treasurer.
Committee for Bonding Trustees, H. L. BRUNER, Chairman, Butler University, Indianapolis; W. A. COGSHALL, Indiana University, Bloomington. (This committee is appointed by the Executive Committee.)
Executive Committee, Officers and Past Presidents.

COMMITTEES FOR 1932-33

Archeological Survey, E. Y. GUERNSEY, Bedford, Chairman.
Auditing, J. B. DUTCHER and J. E. SWITZER, Indiana University.
Biological Survey, B. E. MONTGOMERY, Purdue University, Chairman.
Membership, F. M. ANDREWS, Indiana University, Chairman.
Program, WILL SCOTT, Indiana University, Chairman.
Publication of Proceedings, J. J. DAVIS, Purdue University, Chairman.
Relation of Academy to State, JOHN S. WRIGHT, Indianapolis, Chairman.
Research, A. L. FOLEY, Indiana University, Chairman.
State Library, STANLEY COULTER, Indianapolis, Chairman.
Academy Representative on the Council of A. A. A. S., H. E. ENDERS, Purdue University.
Nominations, (To be announced later).
Junior Academy of Science, H. E. ENDERS, Purdue University, Chairman.
Anniversary Publicity, W. E. EDINGTON, DePauw University, Chairman.

[1] A complete report of the Secretary is filed at the Indiana State Library, Indianapolis, and may be seen on request.

MINUTES OF THE SPRING MEETING

May 19-21, 1932

TURKEY RUN STATE PARK

President Payne called the meeting to order at 7:40 P. M., May 19. Reports were heard from the Editor, Treasurer, the Program, Junior Academy, Membership and Proceedings committees. The meeting was then turned over to Dr. Weatherwax who spoke on his recent Central American trip in search of corn relatives. Friday and Saturday were spent on various field trips in the vicinity.

WINTER MEETING

PROGRAM OF THE FORTY-EIGHTH ANNUAL MEETING OF

THE INDIANA ACADEMY OF SCIENCE

HELD AT

THE UNIVERSITY OF NOTRE DAME

SOUTH BEND, INDIANA

November 17-19, 1932

THURSDAY, NOVEMBER 17, 1932

2:00 p. m. Meeting of Entomologists, Cushing Hall, Room 22.
2:00 p. m. Meeting of Taxonomists, Cushing Hall, Room 5.
6:30 p. m. Executive Committee Dinner, Oliver Hotel.
8:00 p. m. Executive Committee, Business Session, Oliver Hotel.

FRIDAY, NOVEMBER 18, 1932

8:00 a. m. Registration, Concourse, Cushing Hall.
9:00 a. m. General Session, Auditorium, Cushing Hall.
10:30 a. m. Sectional Meetings for Botany and Zoology.
10:30 a. m. Meeting of the St. Joseph Valley Section of the American Chemical Society, Auditorium, Cushing Hall.
12:00 m. Luncheon, University Cafeteria.
1:30 p. m. Technical Sessions for all Sections.
5:00 p. m. Symposium on the Teaching of Freshman College Chemistry, L. A. Test, Chairman, Auditorium, Cushing Hall.
7:00 p. m. Academy Dinner.
8:30 p. m. Public Session. "Mental and Physical Differences in Identical Twins Reared Apart." Dr. H. H. Newman, University of Chicago.

SATURDAY, NOVEMBER 19, 1932

8:30 a. m. Junior Academy of Science, H. E. Enders, Chairman.

MEETINGS OF THE SECTIONS

Bacteriology (12 papers). C. A. Behrens, Chairman.
Botany (37 papers). Paul Weatherwax, Chairman.
Chemistry (16 papers). M. G. Mellon, Chairman.
Geology and Geography (7 papers). C. A. Malott, Chairman.
Physics and Mathematics (17 papers). W. E. Edington, Chairman.
Zoology (27 papers). N. E. Pearson, Chairman.

MINUTES OF THE EXECUTIVE COMMITTEE

The committee met with thirteen members present. Reports of officers followed:

Academy Foundation. Mr. Frank Wade presented a detailed report of the condition of the Foundation funds:

December 1, 1931, balance on hand	$35.71
Total receipts, including interest and other additions	2,600.17
Total	$2,635.88
Investments made, including cost of same	2,465.96
Balance in Indiana National Bank savings account	$169.92

ASSETS

U. S. 4th L. L. Bond E06142095	$50.00
U. S. Treasury Bonds	3,700.00
Muncie Masonic Temple, Preferred	200.00
Standard Oil Company of Indiana, Common	150.00
Balance as shown above	169.92
Total assets	$4,269.92

Biological Survey. Chairman Lyon made a progress report. The committee recommended that a sum not to exceed $100.00 be allowed for clerical aid in final compilation of the bibliography of Indiana biology. It was recommended that the universities of the state be urged to provide adequate facilities for permanent preservation of specimens of Indiana fauna and flora. The report was adopted and the recommendations were authorized.

Editor. Volume 41 of the Proceedings was reported by Editor Cain to have consisted of 538 pages and to have incurred a deficit of $91.00.

The Academy authorized the Treasurer to make available to the Editor from the general fund $150.00.

State Funds (Editor's report, 12-7-32):		
Stafford Engraving Co., for illustrations		$499.95
Burford Printing Co., for printing		1,532.14
Burford Printing Co., extra reprints		150.00
Paid from state appropriation		1,500.00
Balance due Burford's, to be paid from Editor's Funds, which see		$682.09
Editor's Funds:		
Cash on hand, audit of 5-18-32		$1.50
Balance, Irvington State Bank, Indianapolis		123.05
From authors, arrears vol. 40		15.75
From authors, vol. 41		247.47
Special appropriation from Academy treasury		150.00
Total income		$537.77
Editorial expenses, vol. 40	$47.13	
Editorial expenses, vol. 41 to date of audit	21.04	
Burford's on balance due, vol. 41	400.00	
Revenue on checks	.14	
	$468.31	468.31
Balance on hand, First National Bank, Bloomington, 12-7-32		69.46
Author's arrears, vol. 39		$11.20
Author's arrears, vol. 40		61.20
Author's arrears, vol. 41		182.25
From Academy Treasurer, refund for editorial expenses		47.13
Receivable, 12-7-32		$301.78
Balance, First National Bank, Bloomington		69.46
		$371.24
Balance due Burford's, vol. 41		282.09
		$89.15

(Signed) STANLEY A. CAIN, Editor.
WILL MORGAN, Auditor.

Press Secretary. Progress report by Chairman Edington. The Academy authorized subscription to clipping service.

Relation of Academy to State. Chairman Wright reported by telegram that the annual appropriation for the publication of the Proceedings had been cut to $1,000.00 by the special session of the state legislature. (This was reduced to $750.00 by the 1933 General Assembly.)

State Library. Chairman Coulter reported on the condition of the Academy collection and the progress of the new State Library building.

Treasurer. Marcus W. Lyon, Jr., Treasurer, reported up to and including November 9, 1932. The following report is up to and including January 24, 1933:

RECEIPTS

Balance on hand January 2, 1932	$519.99	
Collected from members as dues and initiation fees	837.00	
Amer. Assoc. Adv. Sci.	101.50	
Contributions from friends	10.00	
		$1,468.49

DISBURSEMENTS

Secretary	$223.04	
Treasurer	81.90	
Editor	197.13	
Program Committee	392.96	
Academy Foundation	130.06	
Junior Academy	36.00	
		$1,061.09
Balance in bank January 26, 1933	407.40	
		$1,468.49

(Signed) MARCUS W. LYON, JR., Treasurer.
FRANK W. HORAM, Auditor.

January 27, 1933.

Junior Academy of Science. Chairman Enders gave a progress report.

NEW BUSINESS AND REPORTS OF SPECIAL COMMITTEES

Committee on Bonding Trustees. Chairman Bruner presented a report which was accepted and the committee was authorized to secure the necessary bonds. H. L. Bruner and W. A. Cogshall were authorized to continue as the Committee on Bonding of Trustees and to have custody of the bonds.

Anniversary Publicity. Chairman Edington discussed plans for the fiftieth annual meeting in 1934. The committee was authorized to secure reproductions and cuts of important documents.

Nominating Committee. Chairman Scott reported the following for fellows: Edward Kintner, John E. Potzger and Henry G. Nester.

The Academy authorized the appointment of a committee to consider revision of the constitution with instructions to report at the spring meeting. Stanley A. Cain was made chairman.

MINUTES OF THE GENERAL SESSION

The minutes of the Executive Committee were read and approved. The program for the day was then begun. A brief session followed the annual Academy dinner. The following business was transacted:

The Membership Committee reported the names of applicants for membership. These were all unanimously elected. The Committee on Invitations recommended that the next winter meetings be held at Indiana University between the 15th and 30th of October.

Chairman Scott of the Committee on Nominations made the following report, which was unanimously adopted:

President, Marcus W. Lyon, Jr., South Bend.

Vice-President, M. S. Markle, Earlham College, Richmond.

Secretary, Ray C. Friesner, Butler University, Indianapolis.

Assistant Secretary, W. P. Morgan, Indiana Central College, Indianapolis.

Treasurer, Paul Weatherwax, Indiana University, Bloomington.

Editor, Stanley A. Cain, Indiana University, Bloomington.

Press Secretary, W. E. Edington, DePauw University, Greencastle.

Trustees of the Academy Foundation, Frank B. Wade, Indianapolis (term expires in 1935) and John S. Wright, Indianapolis (term expires in 1936).

REPORT OF THE JUNIOR ACADEMY OF SCIENCE

The Junior Academy of Science met in its second annual session at 9:00 o'clock, November 19, 1932, in Cushing Hall, University of Notre Dame, and was called to order by Dr. Howard E. Enders, Chairman. The adoption of an emblem and a model constitution was reported. The following clubs have become affiliated with the Junior Academy of Science: (1) The Hilltop Nature Study Club, North Madison; (2) the Sciemus Club, Valparaiso; (3) the General Science Club, Junior High School, Bloomington; (4) the Audubon Society, Crawfordsville; (5) the Biology Club, Crispus Attucks High School, Indianapolis; (6) the Chemistry Club, Shortridge High School, Indianapolis; (7) the Science Club, Union City; (8) the Nature Study Club, Indianapolis; (9) the Geography Council, North Side High School, Fort Wayne.

An attendance of 26 members from 4 clubs and 20 visitors was reported. The program consisted of reports, exhibits and talks by members.

BARTON WARREN EVERMANN

ALBIA, IOWA
October 23, 1853

BERKELEY, CALIFORNIA
September 27, 1932

Barton Warren Evermann was born October 23, 1853, at Albia, Iowa, and died at his home in Berkeley, California, September 27, 1932. His parents moved to Carroll County, Indiana, when he was a small boy and he received his primary education in the schools of that county and in

BARTON WARREN EVERMANN

Howard College at Kokomo, Indiana. He taught for a number of years in the country schools of Carroll County and in time achieved the worthy ambition of country teachers of those days in becoming county superintendent of schools. In 1875 he married Meadie Hawkins, one of his fellow country teachers, and about 1880 he and Mrs. Evermann moved to Santa Barbara, California, where they taught for several years.

While teaching in the country schools of Indiana he and his wife became much interested in birds and he began to keep full notes of their migrations and habits. From these notes he prepared the first papers of his bibliography. Up to the time he graduated from Indiana University in 1886 his writings were almost wholly on birds, 24 papers on Ornithology having been published in the "Ornithologist and Oologist," "Auk," etc., between the years 1879 and 1887. Early in his bird studies he began to collect them in order to study more closely their variations and determine their scientific names. Mrs. Evermann soon learned to prepare the skins, and between them they built up a fine private collection of the birds of northern Indiana and southern California.

In those days there were few books on birds and they had at times difficulty in identifying their specimens. However, in 1878 Dr. David Starr Jordan, then Professor of Science in Northwestern (now Butler) University at Indianapolis, issued the first edition of his noted "Manual of Vertebrates," and the Evermanns procured a copy. This, he afterward told me, was the most highly prized book he ever owned. Through it as a medium he began to correspond with its author and soon afterward returned to Indiana and for a time was a student and assistant of Dr. Jordan at Butler. Thus began that long and close association of the two great naturalists which continued up to the last year of their lives.

About 1883 the Evermanns moved to Bloomington and both of them entered Indiana University. The writer at that time was just beginning his work under Dr. Jordan, who was then Professor of Zoology in the University. As fellow students and lovers of nature, Evermann and I began a friendship which lasted through the years.

In those days there existed about a mile west of Bloomington the remnants of a former nursery which, with a big orchard and many pine trees, surrounded an old farm house. This, the old Turner place, was a favorite resort for winter birds in and about the pines and a stopping place for migrants in spring and fall. Thither Evermann and I, armed with shotguns, made our way on many occasions, taking shore larks, cedar waxwings, red-bellied nuthatches, white- and red-winged crossbills and pine and purple finches in winter, and many rare warblers and sparrows in their migrating seasons. At Evermann's suggestion, I prepared in 1886 my first ornithological paper, "The Winter Birds of the Vicinity of Bloomington, Indiana," where I listed with notes 59 species. Evermann the next year prepared his "Birds of Monroe County, Indiana," in which he included 188 species, incorporating my notes on the winter forms. Both papers were published in the "Hoosier Naturalist," a small magazine devoted to local history and nature sketches and published at Valparaiso, Indiana.

In the field Evermann could sight or distinguish the note of a bird for a greater distance than anyone I ever knew. At this time both Mr. and Mrs. Evermann were also much interested in botany, and while collecting birds he also took many of the rarer plants about Bloomington, especially those Ericads, numerous species of which have in Monroe and Brown counties their southern limits in the state. He had also become much interested in Ichthyology, especially fresh water fishes, a natural consequence of his association and work with Dr. Jordan. In 1886 he

published his first fish paper, "A List of the Fishes Observed in Franklin County, Indiana."

Evermann graduated from Indiana University in 1886 with the degree of B. S. and from his Alma Mater he also received the degrees of A. M. in 1888; Ph. D. in 1891 and LL. D. in 1928. After graduating he went to Terre Haute as Professor of Biology in the State Normal School, which position he held until 1891, when he went to Washington as Ichthyologist for the U. S. Fish Commission.

In 1887, when Mrs. Evermann and I both graduated at Indiana University, he secured for me a position as head of the Department of Science in the Wiley (Terre Haute) High School. We were thus associated for four more years, during which we made many collecting trips together, especially to the large ponds in the Wabash River bottoms where we made especial study of the habits of many rare water birds and aquatic plants.

In 1889 the Evermanns sustained a great loss in the burning of the main building of the State Normal School, in which their large collection of bird skins, herbarium and many of their most valuable scientific books were destroyed.

At Washington Dr. Evermann served from 1891 to 1910 as chief in charge of the Division of Scientific Inquiry of the U. S. Bureau of Fisheries and from 1910 to 1914 as Administrator of the Alaska Fisheries Service. In the first named position he sent out each summer parties of three to six persons to collect fresh water fishes in various parts of the United States in order to ascertain the exact distribution of each species known to science. I had the pleasure of serving as assistant on these expeditions during two summers. He also, through Dr. J. T. Scovell, who had a summer cottage on Lake Maxinkuckee, became much interested in the natural history of that fine body of water. For several years he spent part of his vacation in the study of the lake and afterward, with his assistant, H. Walton Clark, published in two volumes a noted work entitled "Lake Maxinkuckee: A Physical and Biological Survey," which is the most complete natural history survey of any lake in North America.

During all these years and in fact until 1930, he was collaborating with Dr. D. S. Jordan. Together they traveled, studied and explored the waters adjacent to Hawaii, Alaska and the Pacific coast and together they wrote and published some of the most important works on Ichthyology which have appeared in this country. Among the most noteworthy of these were "The Fishes of North and Middle America," four volumes, 1896-1900; "American Food and Game Fishes," 1914, a noted popular work which has run through several editions; "The Genera of Fishes from Linnœas to Cuvier," 1917, and "Check List of the Fishes and Fish-like Vertebrates of North and Middle America," 1930.

In 1914 Dr. Evermann resigned from the U. S. Fish Commission and went to San Francisco as Director of the Museum of the California Academy of Sciences. Here he developed many new features and made the museum and the Steinhart aquarium which, through the generosity of Ignatz Steinhart, he founded in 1921, the two largest institutions of their kind west of the Rocky Mountains.

During the last 40 years of his life Dr. Evermann became one of the greatest of the true naturalists of this country, an ilk whose ranks have become almost extinct. His bibliography of 387 titles shows that he published most extensively on fishes and birds, but it contains numerous papers on reptiles and mammals and a few on plants. He believed in studying in its entirety an object afield in its chosen or native haunts—not an infinitesimal part of it beneath a compound microscope. He believed and practiced that *work* is the greatest blessing vouchsafed to man during his few years on the surface of this earth of ours. He was very intolerant of any one, assistant or student, who was indifferent to the work in hand, or of anyone who considered that he had learned enough. He could, if occasion required, write or speak in simple language so that the most abstruse scientific facts were understood by his readers or audience. Originally a teacher, nothing gave him more pleasure than to speak before an audience of young people whose life's work was before them and, says G. Dallas Hanna: "It seemed to us who knew him intimately that his happiest moments were those spent telling of natural history to classes of school children which visited the halls of the California Academy of Sciences." [1]

While living in his later years in a distant state, Dr. Evermann took great interest in Indiana, Indiana University, the State Audubon Society and the Indiana Academy of Science, of which latter he was one of the charter members, and whenever possible he timed his necessary eastern trips so that he could attend the annual meetings of the Audubon Society or of the Academy.

During his final illness, while confined to a hospital, he wrote me several times in regard to the distribution in Indiana of the big Lady's Slipper, *Cypripedium spectabile* Schwartz, and the Leatherwood, *Dirca palustris* L. In one of these letters he said: "Along the west side of the cemetery at Burlington is a wild gorge, not very large, but large enough, where plants, trees, shrubs and flowers are found in great profusion and where birds are always abundant. I have started an inquiry looking toward the acquisition of the little gorge to set it aside as a wild flower and bird sanctuary. I hope to be able to carry it through; to acquire it and then turn it over to the cemetery association to look after it in the future, the expenses of the upkeep to be paid by myself. I expect there are hundreds of similar tracts in the State that might be utilized in the same way."

It is in this cemetery at Burlington that his ashes now rest. There the birds for unknown centuries to come will carol for him their sweetest songs—knowing not that they sing for one who was ever their friend and conservator.

Barton W. Evermann, friend and fellow naturalist of my better days, has solved, as we all must solve, the problem of the great unknown. He filled well the 78 years and 11 months which the God of Nature granted unto him from the eons of eternity. He added greatly to the store of human knowledge. The world is much the wiser and the better for his having been.

W. S. BLATCHLEY.

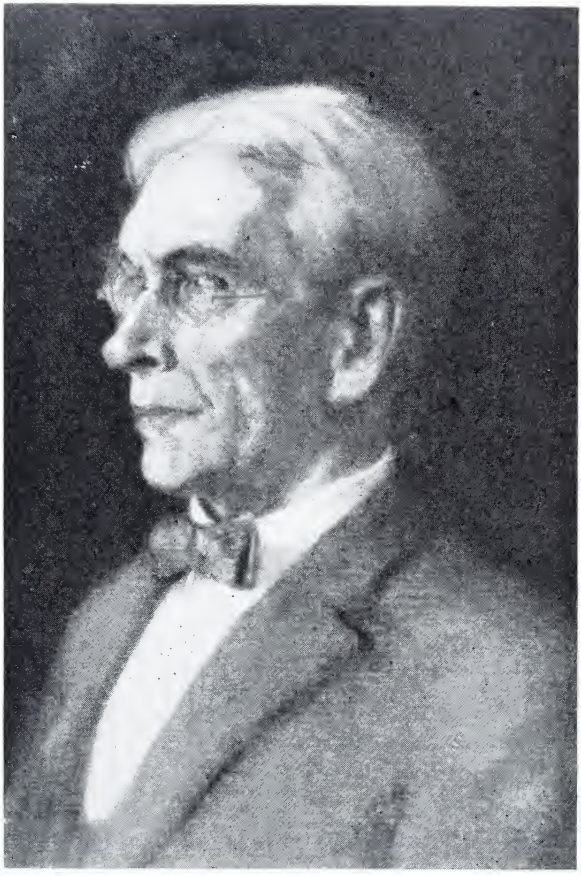
[1] Science, October 7, 1932.

CARL LEO MEES

COLUMBUS, OHIO
May 20, 1853

TERRE HAUTE, INDIANA
April 19, 1932

Carl Leo Mees, M. D., Ph. D., President Emeritus of Rose Polytechnic Institute, died at Terre Haute on April 19, 1932, after a short illness. Funeral services were held at his home in Terre Haute and in Columbus, Ohio, where interment took place. Dr. Mees was unmarried but had a



CARL LEO MEES

number of nephews and nieces, among them being Dr. Otto Mees, President of Capitol University.

Dr. Carl Leo Mees was born in Columbus, Ohio, May 20, 1853, son of Rev. Konrad and Elise (Adam) Mees. His father was a native of Germany and came to this country when a young man, settling first in New York and later coming to Columbus, where he served one congregation for over fifty years.

Dr. Mees' education was received from private instructors. At the age of about eleven years he entered the eighth grade of the public school and was graduated from the Columbus High School in 1869. While a student in high school he acted as assistant to Dr. Thomas C. Mendenhall, his instructor in physics, from whom he received the inspiration which led him to specialize in physics and chemistry.

After completing his high school work Dr. Mees entered Starling Medical College where he came in contact with Dr. Thomas G. Wormley, at that time one of the greatest authorities in the world on poisons and the foremost chemist in legal expert work in the United States. The work of Dr. Mees was along the line of perfecting the methods for the detection and identification of human blood and tissues in suspected murder cases. In the course of this work he devised and perfected a method of microscopic identification which was accepted throughout the profession. He was the first to succeed in photographing different kinds of blood for comparison and exhibition to juries. This work was standardized and accepted in the United States Army and Navy Museum. Some 100,000 blood measurements were made by this method.

In order to qualify properly in court in medico-legal cases at that time the degree of M. D. was universally required. Therefore, Dr. Mees took the medical course parallel with his work in chemistry and received his degree in medicine in 1874. However, he never practiced medicine. The two following years were spent in the Ohio State University, then known as the Ohio Agricultural and Mechanical College, where he devoted his time to the study of physics under Dr. Mendenhall. During this period he continued to act as assistant to Dr. Wormley and to give lectures upon the microscope in Starling Medical College, and upon chemical laboratory practice in Columbus Medical College.

As if all these activities were not enough for one man, the young scientist was associated during this same period with Professor Weber of the Ohio Geological Survey in the analysis of minerals and soils, and personally made some six hundred analyses which were published in the State Reports, 1871-1875. He was also assistant State Gas Inspector for three years, testing all the meters of the State except in Cincinnati.

In 1875 Dr. Mees was elected Professor of Physics and Chemistry in the University of the Public Schools of Louisville, now known as the Louisville Male High School. While there he operated an electric arc light, the first ever seen on the Ohio River, on the steamer Gen. Lytle, by connecting a Wallace generator to the donkey engine of the vessel. He also experimented with the telephone as a commercial proposition.

In 1880 he resigned his teaching position and went abroad for study. He spent some time in the University of Berlin under Helmholz, Kirchoff and Hoffmann; also in South Kensington under Professor Frankland and in London under Dr. Tyndall.

In 1882 he was called to the professorship in Physics and Chemistry at the newly organized Ohio University in Athens, remaining in that position until 1887. During that period he lectured on sound and music at the Cincinnati School of Music, at teachers' institutes and on other occasions. He also carried on experimental studies upon wind velocities

in tornadoes. By reproducing certain observed phenomena in the laboratory, successful measurements were made.

In September, 1887, Dr. Mees was called to the position of Assistant Professor of Physics under Dr. T. C. Mendenhall, who had recently become President and Professor of Physics at Rose Polytechnic Institute, Terre Haute, Indiana. In 1889, Dr. Mees was made Professor of Physics. After the resignation of Dr. Mendenhall in 1890 he acted as Chairman of the Faculty until Dr. Eddy assumed the presidency in 1891. He was made Acting President in 1894 and elected President in 1895, in which position he served until his resignation in September, 1919, when he was made President Emeritus. In 1893, Rose Polytechnic Institute conferred upon him the degree of Doctor of Philosophy.

A memorial service was held at Rose Polytechnic Institute on May 18th, at which expressions of appreciation for the work and personality of Dr. Mees were given on behalf of the community, the alumni and the faculty of the Institute.

At its October meeting the Board of Managers of Rose adopted the following resolution:

"Doctor Carl Leo Mees, President of Rose Polytechnic Institute from 1895 to 1919, when he became President Emeritus, died at Terre Haute on April 19th. In addition to the address by the President of the Board of Managers at the Memorial Service held for him May 18th, the Board wishes formally to record in its minutes its great regret at the passing of Doctor Mees, its sense of loss and its deep appreciation of the services which for so many years he rendered to Rose Polytechnic Institute. As Professor and President, his whole interest was the welfare of the college and the success of the students, and as President Emeritus, his advice was frequently of great assistance to the Board and members of the Faculty."

D. B. PRENTICE.

Dr. Mees' Society affiliations included:

Fellow American Association for the Advancement of Science.
Member American Institute Electrical Engineers.
Member American Microscopical Society.
Member American Physical Society.
Member Society for Promotion of Engineering Education.
Member Association of Science and Mathematics Teachers.
Member North Central Association of Colleges and Secondary Schools.
Honorary Member American Steel Treating Research Society.
Fellow Indiana Academy of Science.
Honorary Member Credit Men's Association.
Honorary Member Scientific Club of Indianapolis.
Honorary Member Vigo County Medical Society.
Honorary Member Vigo County Historical Society.
Honorary Member Exchange Club of Terre Haute.

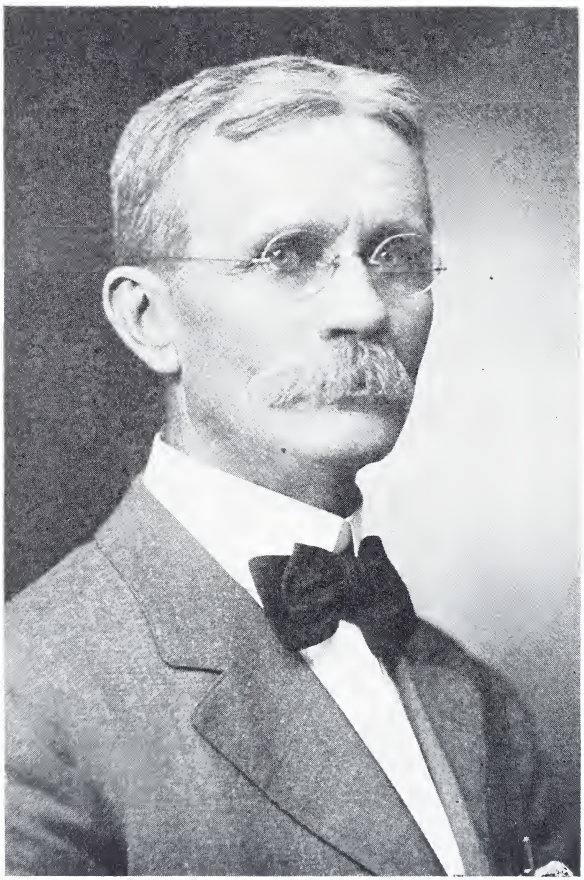
Dr. Mees was general secretary of the American Association for the Advancement of Science in 1889; secretary of Section B of the same, 1888; president of Section B, 1896; president of Section E in 1920. President of Indiana Academy of Science in 1898.

DAVID R. MOORE

RISING SUN, INDIANA
January 9, 1850

OXFORD, OHIO
January 7, 1932

Reverend David R. Moore, D. D., died suddenly at an age of almost eighty-two years at the residence of his son, Dr. H. A. Moore. He received his early education at Rising Sun, Indiana, graduating from Miami University in 1871, four years later from Lane Theological Semi-



REV. DAVID R. MOORE, D.D.

nary, and in 1878 from Princeton Theological Seminary. He was pastor of the Presbyterian Church at Brookville, Indiana, for a number of years, including the period from 1878 to 1886. He also served as pastor at Venice, Logan, South Salem, Bond Hill, Ohio, Frankfort, and Dunlapsville, Indiana, after which he retired from the pastorate and, following the death of his wife in 1922, lived with his sons at Oxford, Ohio.

Dr. Moore was intensely interested in science. He knew most of the scientific men in and about Cincinnati. He made collections of fossils, shells, and archaeological specimens. While at Brookville a small group of persons with similar interests met occasionally at his home. There in 1881 was organized the Brookville Society of Natural History, and he was chosen its first president. Several of his papers were published in the three issues of the Bulletin of that Society from 1885 to 1888. The members of that organization were interested in forming a state Scientific Society. Dr. David Starr Jordan, John P. D. John, John M. Coulter, and John C. Branner, among others, suggested that the Brookville Society of Natural History, as the most active scientific organization in the state, appoint a committee to call and arrange for a meeting to effect such an organization. This task was undertaken by a committee consisting of Dr. Moore, Dr. S. P. Stoddard, and Amos W. Butler. The Indiana Academy of Science accordingly was organized in the Marion County Court House, Indianapolis, Indiana, December 29, 1885. J. P. D. John was chosen temporary chairman. David Starr Jordan was elected President. John M. Coulter, J. P. D. John, and David R. Moore, Vice-Presidents, Amos W. Butler, Secretary, and Oliver P. Jenkins, Treasurer. Soon afterwards, Dr. Moore removed from the State. He was prominent in religious, educational, and scientific circles in Indiana and Ohio. He served for a number of years as a trustee of Miami University. He was a lecturer and an author. At Oxford he was described as one of Butler County's best beloved and most prominent citizens. His was a useful and helpful life. It is a privilege of one who has known him for over half a century to testify to his splendid character, his activity in all good things and his helpfulness wherever he lived. We honor him as one of the founders of this Academy.

AMOS W. BUTLER.

EUGENE DANIEL O'CONNELL

FORT WAYNE, INDIANA
April 11, 1895

SOUTH BEND, INDIANA
October 30, 1932

Eugene Daniel O'Connell, Assistant Professor of Physics at the University of Notre Dame, died suddenly of heart disease at St. Joseph's Hospital on October 30, 1932.

Professor O'Connell spent his boyhood days in the city of his birth, Fort Wayne. In 1913, at the end of his Freshman year at Notre Dame, he enlisted in World War activities, and, later, graduated from Indiana University in 1924.

From graduation to 1927 he taught part time at Loyola University, Chicago, while obtaining a Master's degree from the University of Chicago. He then accepted the position at Notre Dame which he held till his untimely death at the age of thirty-seven years.

While at the University of Chicago, Professor O'Connell specialized in X-Ray spectroscopy and was conducting graduate work in this field. He has had charge of the General Physics Laboratories at Notre Dame

since his appointment and was untiringly instrumental in placing the equipment of these laboratories in first class condition.

In his undergraduate days he was on Notre Dame debating teams, and during the recent political campaign he took a very active part in writing letters to the newspapers and publicly speaking in behalf of the successful party. He was also an active member of the American Legion and Knights of Columbus.

In 1923 he married Miss Anna Rieman, also of Fort Wayne, who, with three daughters and a son, survives him.

All who knew Professor O'Connell admired him for his boundless enthusiasm, his cheerful activity, his appealing good nature, and his lofty ideals of citizenship. By his untimely death the Indiana Academy of Science and the University of Notre Dame lose a loyal member and a zealous teacher. Although he has passed on, his influence remains to help others. We cannot soon forget him.

DANIEL HULL, University of Notre Dame.

ELECTRODE POTENTIALS AND POORLY POISED BIOLOGICAL SYSTEMS

W. P. ALLYN, Terre Haute, Indiana

It was observed by Potter (1910) that during the decomposition of organic compounds by microorganisms, electrical energy was liberated which he measured by placing platinum electrodes into the inoculated and uninoculated portions of a medium separated by a porous partition. He did not interpret his results, however, as an expression of an oxidation-reduction system. It was not until 1920 that the true significance of Potter's observations was pointed out by Gillespie. As a result of studies on water-logged soils as well as pure cultures of bacteria, Gillespie introduced the idea of measuring the reducing intensity of bacterial cultures in terms of electrode potentials.

While reference has been made many times in the literature to the speed of reduction of dyes by bacterial systems, the importance of the "intensity" and "capacity" factors in this connection were not properly emphasized until the analysis of oxidation-reduction phenomena by W. M. Clark (1928) appeared. In order that we may deal with the present discussion in terms of the more modern interpretation of this subject, it may be useful to outline briefly the chief points of his analysis which bear directly on this work.

The accumulation of scientific evidence has so expanded the original significance of the terms "oxidation" and "reduction" that a meaning quite foreign to the original has evolved. It was considered formerly that the progressive addition of oxygen to products gave rise to higher and higher states of oxidation, whereas the loss of oxygen resulted in lower reduced states. All of which is true, but not comprehensive enough to include all reactions falling into these two categories mentioned.

It is known that reduction may be accomplished by the addition of hydrogen as in the case of the reduction of indigo to indigo white. The transformation of a ferrous chloride to a ferric chloride solution by the action of chlorine presents another point of departure from the original conception of oxidation. The ferrous iron ($\overset{++}{Fe}$) has lost two electrons as indicated by the two plus signs, while the ferric iron ($\overset{+++}{Fe}$) has lost three. Then in this transformation of ferrous to ferric iron by the activity of chlorine, the latter acts merely as the absorbent of an electron from the ferrous iron.

Oxidation then may not only be characterized by the addition of oxygen, the loss of hydrogen, but more especially by the loss of electrons. It is implied, of course, that the opposite is true in case of reduction. The reduction of one substance involves the oxidation of another, the former receiving electrons from the latter. Thus, the tendency of one system to reduce another is characterized by the readiness with which

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

it gives up electrons to it. The intensity of this electron transfer may be expressed in terms of electrometric potentials. Of several systems which may be under consideration, the one which has the greater tendency to absorb electrons has an electropotential positive to the others and will oxidize any system with a potential more negative.

It is observed that an electrode of a noble metal (gold, platinum, or mercury) placed in a solution containing an oxidation-reduction system acquires an electron charge increasing with the reducing intensity of the system. The potential differences between this system and that of a potassium chloride calomel half-cell can be measured by connecting the two with a potentiometer and completing the circuit through a potassium chloride agar bridge.

The calomel half-cell is used as a standard of comparison in practical operations because of the ease with which it can be prepared and maintained at a constant value. The normal hydrogen electrode has been selected as the arbirtary zero electrode potential, but it is prepared and maintained at a constant value with difficulty. The normal hydrogen electrode is defined as a platinized platinum electrode held under one atmosphere of hydrogen and immersed in a solution normal with regard to hydrogen ions. The values of the saturated calomel half-cell, at various temperatures, have been determined experimentally, however, in terms of the hydrogen electrode and may be obtained from the tables of Clark (1928).

Electrode potentials are usually recorded as Eh readings, Eh = .150 volts at pH = 7.0 for example. The reading indicates that the difference between the potential of the system in question at pH = 7.0 and that of the normal hydrogen electrode is 150 millivolts, the former at pH = 7.0 being negative to the standard hydrogen electrode which, by definition, is pH = 0.

The necessity of stating the pH of the system at the time at which the reading is taken becomes obvious, since the Eh reading is affected also by a change in acidity. The Eh reading of ideal systems, such as the hydrogen and quinhydrone electrode, becomes .06 volts more positive progressively for each unit increase in hydrogen ions. Referring again to the reading above, the O-R potential of the system is not actually 150 millivolts negative to normal hydrogen electrode since the value of the latter is calculated at pH = 0, and that of the system to be measured is given at pH = 7.0. There are 7 units in pH variation between the two, which according to the figures above (7 x .06 volts) makes the system to be measured 420 millivolts more positive than it would appear if reduced to the same pH as the normal hydrogen electrode (pH = 0).

The change of .06 volts for each unit change in pH seems to hold for ideal systems, such as the hydrogen or quinhydrone electrodes, but it is subject to certain variations in complex biological systems. In sterile bacteriological media, however, pH changes can be prevented by buffers and the reducing intensity of the system in terms of potential-time changes easily noted. Even where pH changes occur, in such cases as bacterial fermentations, if these changes be followed, the potential-time changes offer some very valuable data for studying the electromotively active properties of the systems.

Poorly poised systems. A system is said to be poorly poised when it fails to resist a change in potential easily upon the addition of small amounts of electromotively active substances. This characteristic of O-R systems may be considered somewhat analogous to poorly buffered solutions in hydrogen-ion studies. The experiences of the writer indicate that many biological systems probably fall into this category. Poorly poised systems present certain difficulties in making electrometric potential measurements with a simple potentiometer circuit as will be discussed presently.

Vacuum-tube potentiometer circuit. The use of a simple potentiometer circuit has been found unsatisfactory for making O-R potential measurements in poorly poised systems due to polarization effects produced while finding balance. Particularly is this true of sterile bacteriological media. The magnitude of the current passing through the simple potentiometer circuit sets up a change of potential at the electrode, masks the potential produced by the medium itself, and leads to certain discrepancies in measuring the true potential of the medium in question.

Polarization effects may be avoided by the use of a vacuum-tube potentiometer circuit. A circuit of this type has been described by Allyn and Baldwin (1932) and will be referred to only briefly here. The principal feature of this circuit consists in reducing the magnitude of the current passing through the system to a very low value while making measurements. The system to be measured and the potentiometer are connected to the grid circuit of the vacuum-tube by a two-way switch. The galvanometer is placed in the plate circuit. After balancing the closed vacuum-tube circuit, the EMF to be measured and potentiometer are brought into the grid circuit by the two-way switch. This changes the grid bias which in turn changes the plate current, and a deflection is evidenced in the galvanometer. By giving the potentiometer a value equal to and opposite that of the EMF to be measured, the grid bias attains its original value; the plate current, likewise, becomes as before; and the galvanometer again reads zero. Hence, the reading on the potentiometer indicates the potential difference between the standard calomel half-cell and the system under investigation.

As stated above, the system to be measured is made a part of the grid circuit during the operation. The magnitude of the current in this circuit depends upon the negativity of the grid bias. The initial negative grid bias was so adjusted that the grid current had a very low value of approximately 10^{-10} amperes. This current had a very negligible polarizing effect on the electrodes in the systems studied.

Preparation of electrodes. There have been many references in the literature to the construction of electrodes, yet a beginner in the work encounters many difficulties that must be solved through experience. It would appear that the actual preparation of the electrode is of greater concern than the kind of regal metal used in its construction. The writer found no appreciable difference in electrodes made of gold or platinum. Discrepancies seemed to be caused, in the main, by fractures in the glass about the electrode or by improper cleaning.

The most satisfactory electrodes were obtained by sealing a small 22-gauge platinum wire in the end of a 5 to 6 mm. soft glass tubing.

The end of the glass tubing was held over a flame and glass permitted to flow in until the hole was almost closed, leaving barely enough room to accommodate the 22-gauge wire. The platinum wire was then inserted and sealed in firmly with a flame. An excess of glass about the seal was avoided. This type of electrode suspended in distilled water withstands autoclaving very well without cracking.

Jena glass was used also for sealing the platinum wire in the end of an ordinary soft glass tube and proved very successful, but required more time and skill than the simpler method just described. Pyrex tubing was investigated also, but the difference in the coefficient of expansion between it and the platinum rendered this glass less desirable than the ordinary soft glass tubing, especially when steam sterilization is employed.

Great care should be exercised in the cleaning of the electrodes, if comparable readings are to be obtained. The practice of suspending the

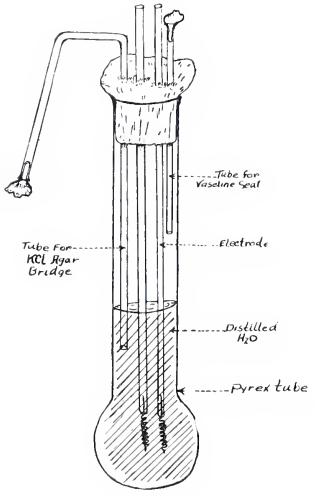


Fig. 1.

electrodes in hot chromic-sulphuric acid for some 30 minutes, rinsing thoroughly in distilled water, and flaming in an alcoholic flame, proved very satisfactory.

Some discrepancies were noted in the initial potential readings of electrodes in the same system depending upon the method of sterilization. Electrodes autoclaved while suspended by a cotton plug in empty Pyrex tubes, gave readings some 50 millivolts negative to those sterilized under water. This difference can hardly be attributed to microscopic fractures in the electrodes sterilized in steam. It was possible to have perfect checks between electrodes sterilized in this manner. Further, the difference between electrodes sterilized both in steam and under water was overcome and the electrodes brought into close agreement by intensifying the oxidation-reduction properties of the system by the addition of an oxidizing or reducing agent. It would occur that the surface of the electrodes suffers slight modifications, depending upon the method of sterilization and the modification is reflected by the initial readings of the

electrodes held in rather inactive oxidation-reduction systems. This difference was overcome after a time also by media placed under a vaseline seal. Greater consistency was obtained, however, with electrodes sterilized under water and it is believed that this practice is to be recommended.

Set-up for potential readings in sterile bacteriological media. The set-up depicted in Figure 1 was found eminently practicable for making O-R measurements of sterile bacteriological media. Large test tubes (1 x 8 inches) were heated and blown out to a uniform size at the base to prevent the electrodes from making contact with the glass. It will be noted that two electrodes, a tube for the KCl agar bridge, and a tube for the vaseline seal are firmly fixed in a cotton plug and set in the tube for autoclaving. The apparatus was cooled after sterilization, the KCl agar bridge filled with saturated KCl agar, and the barrels of the electrode with metallic mercury for making circuit contact. One end of a small rubber tube was fitted over the end of the tube for the KCl agar bridge and the other end held in the mouth. In the meantime, the KCl agar was prepared in a deep test tube and held in readiness aseptically at about 55° C. The whole apparatus was lifted from the tube in which it was autoclaved, the tube for the KCl agar lifted at a slight angle, inserted into the KCl agar, and filled by suction on the rubber tube. The end of the rubber tube was clamped momentarily to permit the agar to jell and the apparatus returned to the pyre tube in which it was sterilized.

The barrels of the electrodes were then filled with mercury for making circuit contact by means of long capillary pipettes. It would naturally follow that the system to be investigated has been prepared in a vessel of similar size and construction to that employed in sterilizing the electrodes in order to accommodate a complete transfer of the apparatus just described for O-R potential studies.

If it be desired to follow the potential time changes of the medium under a vaseline seal, the moisture may be driven from the sides of the tube with a mild flame and sterile warm vaseline introduced to the depth desired over the medium with a pipette through the tube in the cotton plug inserted for this purpose.

If aerobic or anaerobic fermentations be desired, the medium may be inoculated just before the introduction of the electrodes and handled accordingly. The writer has prepared several hundred systems as described here with no appreciable difficulty with outside contamination.

REFERENCES

Allyn, W. P. and Baldwin, I. L., 1932. Oxidation-Reduction potentials in relation to the growth of an aerobic form of bacteria. Jour. Bact., 23:369-398.

Clark, W. M., et al., 1928. Studies on oxidation-reduction. I-X Hygienic Lab. Bul. 151.

Gillespie, L. J., 1920. Reduction potentials of bacterial cultures and of water-logged soils. Soil Science 9:199-216.

Potter, M. C., 1910. On the difference of potential due to the vital activity of micro-organisms. Proc. Univ. Durham Philosophical Soc. 3:245-249.

EVALUATION OF ANTISEPTICS BY TEST TUBE METHODS

H. M. Powell and W. A. Jamieson
(Lilly Research Laboratories, Indianapolis, U. S. A.)

Introduction

Many different types of chemicals, including mercurials, dyes, surface tension depressants, and other substances, with water, alcohol, glycerin, and other solvents, are used at present for antiseptic purposes. Considerable variation is noted when various antiseptics are tested by test tube methods using different bacteria. Variation is also noted in results reported by different individuals dealing with the same antiseptic and the same bacterium.

Formerly cultures of typhoid bacilli were extensively used in the laboratory to test antiseptics. In recent years, however, staphylococci, on account of their ubiquity, resistance, and frequency of infection, have largely supplanted the typhoid bacillus as the main test organism. It appears probable that many of the marked differences reported in the antiseptic action of various chemicals against these two species may be attributed to the physical differences of these forms in artificial culture. The typhoid bacillus grows in peptone media rather regularly as an even emulsion, while the staphylococcus grows in grape-like clusters and zoogleal masses which in turn are often clumped in granules of macroscopic size. Lack of more uniform antiseptic action in the laboratory against such physically dissimilar bacteria as typhoid bacilli and staphylococci in artificial culture, therefore, should in a measure be anticipated. The additional factor of chemical selectivity, such as is evidenced in the Gram stain reaction, undoubtedly explains certain other irregular antibacterial properties; however this phase of antiseptic action will not be dealt with here.

As long ago as 1903 Andrews (1) called attention to the fact that mercuric chloride and other mercurials, although used in practical procedures as effective antiseptics, gave unsatisfactory test tube germicidal results with *Staphylococcus aureus* in peptone media. He attributed this lack of complete killing of all bacteria in the culture dose to the zoogleal manner of growth of this organism in ordinary peptone broth cultures. Later Shippen (2) in 1928 called attention to this same phenomenon in tests of mercuric chloride as well as of certain dyes.

Also, it has been shown that some antiseptics which contain surface tension depressants and alcohol as a solvent, while exhibiting considerable antiseptic effect in watery media tests in the laboratory, are almost devoid of antiseptic action when tested against bacteria in a semisolid fibrin medium, thus simulating to some extent the conditions of animal tissues (3). Thus it appears that in many cases rather excellent test tube assays of antiseptics may not be translatable into terms of effectiveness in tissue antisepsis due to the simple fact that semisolid tissues may block the antibacterial mechanism entirely.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

The variable conditions of testing antiseptics against any particular organism which should receive attention include (a) physical condition of the test culture and the relation of this to the medium and temperature of growth, (b) presence of protein, especially semisolid material such as fibrin, (c) temperature of medication, and (d) extent of culturing to determine presence of viable bacteria following medication. The purpose of this paper is to report the action of some commonly used antiseptics upon the staphylococcus under such varied conditions of testing.

EXPERIMENTAL

In the following experiments regular commercial solutions of Merthiolate 1-1000, designated as Antiseptic "A," and three other well known commercial antiseptics designated here as Antiseptic "B" 1-500, Antiseptic "C" 1-1000, and Antiseptic "D" 1-50, were used along with mercuric chloride 1-1000 and various dilutions of phenol for comparison. *Staphylococcus aureus*, Insecticide and Fungicide strain No. 209, was used as the test culture. The stock culture was maintained on beef extract agar slants made with Armour peptone in the regular manner (4). Broth test cultures were prepared in beef extract Armour peptone broth medium, and consisted of the first, second, third, or later, broth cultures in a series originally beginning with the growth on agar.

It may be pointed out that succeeding subcultures of the test organism in Armour peptone broth are frequently increasingly granular in texture and quite unsuitable for biological experimentation (including agglutination, phagocytosis, et cetera), and lead only to confusion if used in chemical antiseptic experiments. Unusual degrees of "resistance" to phenol and other chemicals developed in this way, therefore, includes resistance of masses of cocci which obscures resistance of individual bacteria, and is highly artificial. Low surface tension and "wetting-out" properties of antiseptics promote more rapid killing of such masses of cocci in the test tube. However, these properties are blocked and do not operate in blood clot or protein of the semisolid consistency of tissues.

Table 1 shows a summary of certain comparative germicidal tests selected from a large number conducted during the past year. In these tests *Staphylococcus aureus* culture No. 209 in Armour peptone broth was used and in some instances probably an unusual severity of test conditions has been imposed on the germicides. In these particular tests various degrees of granulation of the test culture were noted, and it was found that if the test culture was quite rough, granular, pellicled, and precipitated, an enhanced resistance to mercurials in aqueous solution at 20° C. resulted, without much change being noted in resistance to chemicals having special wetting-out properties including phenol, alcohol, and surface tension depressant preparations. It may be noticed quite regularly that the test culture No. 209 is unusually granular in Armour peptone broth when grown at 37° C. It has been our experience that this granular characteristic is much less pronounced in similar broths prepared with some other peptones including Parke Davis, Witte, Berna, and Proteose peptones. It appears also that rough culture characteristics, although affecting the outcome of many 20° medication tests, do not have a parallel adverse effect on antiseptic test results of aqueous mercurials when medication is conducted at body temperature.

In conducting the tests recorded in the first column of Table 1 the stock strain of *Staphylococcus aureus* No. 209 was transferred weekly for ten weeks on the usual Armour peptone beef extract agar. A first generation Armour peptone broth culture was then prepared from the last agar culture, incubated twenty-four hours at 37° C., and then subjected to the test, using six germicides, including phenol, as shown.

A dilution of 1-40 phenol killed and 1-50 phenol failed to kill. All of the other five germicides in the dilutions used failed to kill the test culture under these conditions. The experiment shows that an artificial resistance may at times be obtained in a test culture such that both aqueous mercurials and germicides having enhanced wetting-out properties, such as germicide "C" and phenol, fail to kill the entire inoculum of test culture. Usually the first culture generation in broth is not regarded as particularly "resistant."

The test results recorded in columns 2 and 3 in Table 1 show that succeeding broth cultures of staphylococci grown at 37° C. may be quite granular, and would be judged unfit for routine biological tests such as agglutinin and opsonin measurements. When such cultures are medicated for five minutes at 20° C. with mercurials in aqueous solution, incomplete killing may result, while if medicated at 37° C. generally complete killing of the entire inoculum takes place. In such tests using granular culture it may be repeated that both temperature and wetting-out properties of the antiseptic affect the outcome of the tests. Both the microscopic and macroscopic characeristics of such staphylococcal culture are markedly different from those noted in typhoid bacillus cultures, for example, and it appears that in ordinary test methods these more fundamental factors are not generally recognized.

In connection with another series of experiments (using Kendall and other high protein-containing media) we have repeatedly noted the fact that staphylococci grow under such conditions as single forms or diplococci. The clumps seen in the usual laboratory peptone media do not appear here, and attention was directed to a possible bearing which this may have on tissue antisepsis in relation to test tube evaluation methods. It may be said that growth in the high protein media is not so "vigorous" as in peptone broth, and also that such media are "unfavorable" media; however, it would appear that staphylococci in infected tissue in nature have grown in a medium more like the best protein media than artificial peptone media. These are the important organisms in tissue antisepsis. Also it is readily found that the "phenol-resistance" of staphylococcal cultures without the grape-like clumps is only slightly less than that of the usual laboratory cultures, thus corresponding more nearly with other cultures such as typhoid and coli which regularly appear in the laboratory as homogeneous emulsions.

We have tested aqueous mercurials further in a comparative way by test tube methods so modified as to obtain test culture in even emulsions. This may be accomplished in various ways without changing the nature of the medium, one of the simplest of which is allowing the test culture to grow at room temperature instead of at 37° C. By this means the granulation of the culture is greatly delayed. Also if there is logic in conducting antiseptic tests in the laboratory at 20° C., it may be assumed that culture produced under similar conditions should be the

TABLE 1. SUMMARY OF COMPARATIVE GERMICIDE TESTS AGAINST STAPHYLOCOCCUS CULTURE 209

Medication conducted for five minutes followed by plantings into 250 cc. bottles of Armour peptone broth unless otherwise indicated

Germicide	Test temp. 20°C. First generation culture. Grown at 37°C. Very granular.	Test temp. 20°C. Third genration culture. Grown at 37°C. Very granular.	Test temp. 37°C. Third generation culture. Grown at 37°C. Very granular.	Test temp. 20°C. Third generation culture. Grown at 20°C. Smooth and even.	Test temp. 37°C. Fibrin or "white clot" plates.
Merthiolate 1-1000 (Mercurial)	+	±	—	—	—
Germicide B 1-500 (Mercurial)	+	+	—	—	+
Germicide C 1-1000 (Non-mercurial)	+	—	—	—	+
Germicide D 1-50 (Mercurial)	+	+	+	+	+
Mercuric Chloride 1-1000 (Mercurial)	+	+	—	±	+
Phenol 1-40	—	—	—	—	+
50	+	—	—	—	+
60	+	+	—	—	+
70	+	+	—	+	+
80	+	+	+	+	+

All cultures used were Armour peptone broth cultures planted from Armour peptone agar cultures.
Legend: + = growth; — = no growth; ± = irregular.

object of the test. Table 1, column 4, shows results of germicide tests against quite even homogeneous cultures of *Staphylococcus aureus* No. 209 which had been grown at room temperature for twenty-four or forty-eight hours. The tests were otherwise conducted in the usual way, and it appears that the "phenol-resistance" is not much different from that determined with twenty-four hour culture grown at 37° C. The results also show that Merthiolate and germicides "B" and "C" are effective against smooth staphylococcus cultures in vitro, and support the idea that the usual Armour peptone broth cultures grown at 37° C. introduce an artificial factor, i. e., granulation and clumping of masses of bacteria, not present in the original *B. typhosus* tests.

Table 1, column 5, shows the results of further special comparative tests against staphylococci embedded in poured "white clot" (fibrin) agar plates. Each plate contained 0.1 cc. of staphylococcus broth culture and 15 cc. of solid medium. The medium consisted of 50 per cent fresh oxalated plasma and 50 per cent of the usual beef extract agar to which calcium chloride was added, at the same time as the test culture, when the plates were poured. Such plates were exposed to 10 cc. quantities of the various germicides for five minutes, followed by removal of the latter and subsequent incubation of the plates. When Merthiolate was used, uniform sterilization of the plate was accomplished as verified by subculturing, while when other germicides were used growth always resulted. It is certain that tests of this general nature evaluate antibacterial properties of antiseptics (3) more nearly possible of realization in actual tissue antisepsis than the properties indicated by most single test tube methods.

CONCLUSION

Most antiseptic test tube assay methods using staphylococci, when applied to certain aqueous antiseptics such as mercurials, may introduce artificial conditions not present in the older tests using typhoid bacilli. The unique zoogleal and granular manner of growth of the staphylococcus in peptone broth may readily lead to artificial and excessive degrees of mercurial "resistance" not found in smooth cultures nor noted in tests conducted by medicating these bacteria more nearly as in tissue antisepsis.

REFERENCES

1. Andrews, F. W. Observations on the resistance of Staphylococcus pyogenes aureus to perchloride of mercury. Trans. Path. Soc. of London, 1903, 54:74-78.

2. Shippen, L. P. A fallacy in the standard methods of testing disinfectants. Amer. Jour. Pub. Health, 1928, 18:1231-1234.

3. Powell, H. M., and Jamieson, W. A. Comparative studies on Merthiolate with reference to laboratory evaluation and human tissue antisepsis. Proc. Ind. Acad. of Science, 1931-32, 41:249-256.

4. Ruehle, G. L. A., and Brewer, C. M. United States Food and Drug Administration Methods of Testing Antiseptics and Disinfectants. U. S. Dept. of Agri. Circular 198, Dec., 1931.

THE INFLUENCE OF ANTISEPTICS ON PHAGOCYTOSIS

H. M. POWELL and W. A. JAMIESON
(Lilly Research Laboratories, Indianapolis, U. S. A.)

INTRODUCTION

Inasmuch as phagocytosis of invading bacteria and foreign substances is a natural immunity mechanism of the first order, and closely similar to such vital physiological processes as digestion and assimilation, it becomes of interest to study any proposed *artificial* antibacterial methods, such as chemical antisepsis, in relation to possible injurious effects upon this *natural* mechanism. Certain desirable characteristics of the most promising antiseptic have heretofore been pointed out (1, 2, 3, 4, 5). These include quite naturally low tissue toxicity and adequate antibacterial qualities in media of the general nature of tissues. Coupled with these qualities may be added a most favorable bacteria: tissue index according to the refined methods set forth by Buchsbaum and Bloom (6), together with the property of promoting healing and repair (7).

Most of these properties have been qualitatively and quantitatively measured for Merthiolate. The study reported here was made to obtain additional information concerning the comparative effects of this chemical upon the process of phagocytosis.

EXPERIMENTAL

The materials used in these tests included, (1) staphylococcus cultures, (2) antistaphylococcus horse serum, (3) guinea pig leucocytes, (4) a series of dilutions of Merthiolate and other commercial antiseptics prepared with physiological saline and the latter alone as a control, and (5) sufficient capillary pipettes, slides, et cetera, for conducting the test.

The staphylococcus culture always consisted of a beef extract broth culture incubated twenty-four hours, after which it was diluted and shaken up with nine parts of saline to produce a homogeneous suspension of desired turbidity.

The antistaphylococcus horse serum was taken from a lot prepared by administering a series of intravenous and subcutaneous doses of staphylococci and their broth culture products to horses over a period of several months. The serum so obtained was concentrated and purified by well known salting-out methods and the pseudoglobulin fraction was utilized.

Guinea pig leucocytes were obtained just previous to each test by washing out with citrated saline the peritoneal exudate resulting in guinea pigs treated twenty-four hours previously with a 5 cc. intraperitoneal dose of 2 per cent aleuronat suspension. Following the emulsification of this exudate, largely made up of polymorphoneuclear cells, in warm citrated saline, centrifugation was done and the cells resuspended in warm saline and placed in the water-bath until used in the tests.

Three antiseptics listed as follows were used in these tests: "A," Merthiolate Solution No. 45, 1:1000, and saline dilutions of this giving 1:5000 and 1:10,000 concentrations; "B," a widely used mercurial antiseptic 1:500 commercial solution and saline dilutions of this giving 1:5000 and 1:10,000 concentrations; and "C," a widely used non-mercurial anti-

TABLE 1. Influence of Antiseptics on Staphylococcal Phagocytosis

Antiseptic Dilution	Leucocyte Suspension	Staphylococcus Culture 1:10	Staphylococcus Serum 1:10	Phagocytosis Observed
0	1 unit	1 unit	1 unit	Complete; all leucocytes engorged.
Saline 1 unit	1 unit	1 unit	0	Very slight; nearly all cocci free.
Saline 1 unit	1 unit	1 unit	1 unit	Complete; all leucocytes engorged.
Merthiolate Sol. "A" 1:1000; 1 unit	1 unit	1 unit	1 unit	Moderate phagocytosis; many free cocci, however.
Merthiolate Sol. "A" 1:5000; 1 unit	1 unit	1 unit	1 unit	As above
Merthiolate Sol. "A" 1:10,000; 1 unit	1 unit	1 unit	1 unit	Complete; all leucocytes engorged.
Antiseptic "B" 1:500; 1 unit	1 unit	1 unit	1 unit	Slight phagocytosis; all leucocytes shrunken; many free cocci.
Antiseptic "B" 1:5000; 1 unit	1 unit	1 unit	1 unit	As above
Antiseptic "B" 1:10,000; 1 unit	1 unit	1 unit	1 unit	Good phagocytosis but not complete; few free cocci.
Antiseptic "C" 1:1000; 1 unit	1 unit	1 unit	1 unit	No phagocytosis; leucocytes clumped together and disintegrating.
Antiseptic "C" 1:5000; 1 unit	1 unit	1 unit	1 unit	Slight phagocytosis; leucocytes clumped and ruptured; many free cocci.
Antiseptic "C" 1:10,000; 1 unit	1 unit	1 unit	1 unit	Moderate phagocytosis; many free cocci, however.

septic 1:1000 commercial solution and saline dilutions of this giving 1:5000 and 1:10,000 concentrations; also saline for controls.

The technique for conducting the tests was that commonly used in opsonic examinations. Using suitably prepared Wright capillary pipettes, one drop each of leucocyte suspension, staphylococcus culture, stapylococcus serum, and antiseptic dilutions were thoroughly mixed, then drawn up into the pipette again and the tip of the latter sealed and placed at 37° C. for fifteen minutes. A saline control was used for the serum and for the antiseptic dilutions. After incubation, the contents of each capillary pipette was smeared and stained as in blood work.

In these tests it is to be noted that we attempt to evaluate the total coincident effect of the antiseptic upon the three factors in phagocytosis; namely, leucocytes, bacteria, and immune serum, and this would appear to be the condition obtained in chemical tissue antisepsis. Heretofore certain phagocytosis-antiseptic tests have been conducted subjecting at first only the bacteria and serum to the action of the antiseptic, following which the leucocytes were added.

Table I shows the results of these antiseptic-phagocytosis tests. A dilution of immune serum of 1:10 without added complement was sufficient to cause complete phagocytosis of the test dose of culture by the dose of leucocytes used, and practically all leucocytes were engorged with cocci, which were too crowded to count. Substitution of saline for serum resulted in only slight phagocytosis in which a leucocyte here and there was found to contain a pair or a few cocci. Addition of saline to a leucocyte-culture-serum mixture resulted as in the first instance in complete phagocytosis. The additional tests with the series of antiseptic dilutions have been recorded in the table as indicated. In the use of each antiseptic it was aimed to record the pronounced differences in phagocytosis in comparison with the normal control.

In these tests Merthiolate shows less interference with phagocytosis and less injury to the leucocytes than either antiseptic "B" or "C." Antiseptic "B" allowed greater phagocytic activity with less leucocyte injury than Antiseptic "C." Possibly the low surface tension value of Antiseptic "C" (32.1) was partly responsible for its particularly destructive effects. The leucocytes in the stronger Antiseptic "C" solutions were clumped together and quite uniformly ruptured and disintegrated. Naturally under such conditions but slight phagocytosis occurred.

SUMMARY

In the tests described in this paper it is shown that all three antiseptics tested retard phagocytosis in varying degrees. Of the three, Merthiolate interfered least with phagocytosis and causes the least amount of damage to the cells.

REFERENCES

1. Powell, H. M. and Jamieson, W. A. Merthiolate as a Germicide. Amer. Jour. Hyg., 1931, **13**:296-310.

2. Jamieson, W. A. and Powell, H. M. Merthiolate as a Preservative for Biological Products. Amer. Jour. Hyg., 1931, **14**:218-224.

3. Marshall, M. S. Merthiolate—A New Antiseptic. California and West. Med., 1931, **35**:43-44.

4. Marks, H. H., Powell, H. M., and Jamieson, W. A. Merthiolate as a Skin Sterilizing Agent. Jour. Lab. and Clin. Med., 1932, **17**:443-449.

5. Powell, H. M. and Jamieson, W. A. Comparative Studies on Merthiolate with Reference to Laboratory Evaluation and Human Tissue Antisepsis. Proc. Ind. Acad. Sci., 1931 (1932), **41**:249-256.

6. Buchsbaum, R. and Bloom, Wm. Relative Toxicity of Antiseptics and Tissues in Cultures. Proc. Soc. Exp. Biol. and Med., 1931, **28**: 1060-1064.

7. Powell, H. M., Jamieson, W. A., and Kempf, G. F. The Healing Properties of Merthiolate. Amer. Jour. Hyg., 1932, **15**:292-297.

THE USE OF GERM FREE GUINEA PIGS IN BACTERIOLOGY

1. PRELIMINARY REPORT CONCERNED ESPECIALLY WITH TECHNIQUE

J. ARTHUR REYNIERS, University of Notre Dame

The problem of raising animals in a germ free condition has intrigued many bacteriologists philosophically but has not been followed by much experimental investigation. Consequently there is a dearth of evidence in the literature concerning this problem. No doubt the popular aspects with which the problem has always been presented together with the technical difficulties involved has resulted in the casual interest with which it has been treated. The available evidence shows much contradiction and the problem is today far from being practically settled in regards to many animal forms. With guinea pigs, however, evidence appears to support the view that the young may be obtained and raised in a germ free state.

The present series of experiments on germ free animals were initiated by a desire to obtain living culture media, free from contaminating influences and as near to natural conditions as possible for use in investigations concerning microbial heredity and change. When used for investigations of this nature the problem, in this instance, assumes a practical aspect. Such animals in a germ free state present ideal testing grounds for this type of work and also for investigations concerning bacterial associations. For example it is possible to add one bacterial cell or a certain cell from a particular strain to a germ free animal and watch the changes which occur in the bacteria. It is also possible to build up an artificial intestinal flora by adding the constitutent organisms one by one. Germ free animals also offer a rare opportunity to study phage and filterable stage developments directly.

Guinea pigs were chosen as experimental animals because they are easy to infect, easy to work with, and are born, normally in a more or less mature condition. The young pigs are obtained by caesarian section and are raised in a special cage. Such apparatus while necessarily complex must allow easy access to the animal without exposing it to the dangers of infection. Many physiological factors enter into the operation and raising of germ free animals. A consideration of these factors will be taken up in a later publication. For the present it must suffice to say that the adult female must be within a few days of term and should be anesthesized with a compound similar to sodium amytal. If more than one foetus is present it is seldom possible to obtain more than the first one in a satisfactory state for the experiment. The young pig once it is placed within the feeding cage must be fed at short intervals,

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

day and night, until it can not only shift for itself in the matter of food, but can digest what it eats. The question of diet has presented many difficulties especially during the early life of the pig. The difficulty of obtaining suitable food after it has been sterilized in the autoclave is still a matter of experiment.

Mortality is high for the first few days of life and its chief contributing causes might be listed as, damp air, irregularity in the feeding schedule, temperature changes, shock following the operation, diet and causes which cannot be exactly determined.

In my experiments with germ free animals the usual controls were set up. Air supply, food, nasal washings, surface of the skin and the water used in the experiments were brought into contact with different culture media. The usual microscopic tests on the blood and exudates of the animal were made after its death. It might be remarked, however, that no attempt has been made up to the present to test for filterable vira or other submicroscopic principles.

Up until the present time I have been concerned with the design of the apparatus and technique used with the different steps in obtaining germ free guinea pigs, in an attempt to simplify and develop a more practical technique. The apparatus used for this purpose may be seen in my laboratories. A full description of the apparatus together with the methods employed in this work will be submitted to the editors of the *Journal of Bacteriology* at a later date. In working with the apparatus it has been necessary to operate a certain number of animals for test purposes. The data and results concerned with these operations might be summarized as follows:

Eighteen female guinea pigs which might be counted as part of the experiment reported at this time have been operated during the course of two years. These animals were delivered of 43 young, 24 of which were delivered alive. The high mortality in this instance might be accounted for by technical factors such as handling, use of improper anesthetics, improper care of the delivered animal, etc. Of the 24 pigs delivered alive only six animals were delivered germ free into the incubator. Three of these animals developed bacterial infections resulting from contamination of food, handling or faulty apparatus. The three pigs which were shown germ free, within the limitations of the aforementioned controls gave the following results: one lived four days and was killed after it became much weakened from faulty diet, one pig lived five days but died from unknown causes (probably improper feeding intervals or improper food) and one lived eight days and was then killed in an apparently normal condition.

Operating for germ free animals and their further culture presents a good many technical difficulties. Good assistants, and experience in details of the operation are necessary to the work. Animals in a germ free state delivered with the present technique require the closest attention as to feeding details. The physical strain placed on the operator in nursing these animals is great. Since the work requires night and day attention for the first few days and more or less constant attention after this period and is tedious it is seldom possible to continue the experiment for a long period of time unless assistance is at hand. No

doubt after the animals have been carried over the most difficult period and are being fed at longer intervals they will require less attention if the apparatus is properly constructed. In the final analysis the experiment is largely a matter of mechanics.

These difficulties are mentioned not to dicourage but to explain the abberrant results reported on the first series of experiments. More recent experiments gave better results. Certainly the value of such animals in experimental investigations concerning bacteriophage, filtrable vira and life cycles warrant further investigation along these lines.

SUMMARY

It is my purpose in this paper to point out the practical possibilities of using germ free animals in bacteriological investigation especially when the research concerns life cycles or change of bacteria. Experiments show that guinea pigs can be obtained and raised in a germ free condition and put to practical use only when the technique and apparatus is especially adapted to that end. It is believed that the apparatus shown in my laboratories simplifies the technique and adapts it to this practical end.

THE MECHANIZATION OF CERTAIN BACTERIOLOGICAL PROCEDURES

A CONSIDERATION OF THE FACTORS INVOLVED IN MECHANIZING SINGLE CELL TECHNIQUE AND THE PLATING METHOD OF COUNTING VIABLE BACTERIAL CELLS

J. ARTHUR REYNIERS, University of Notre Dame

This paper is concerned with a discussion of the mechanization of two important bacteriological procedures, (1) single cell isolation and culture, (2) the plating out of bacterial cells in a nutrient agar for the purpose of estimating the viable cells.

Single cell methods are important in selecting pure strains of bacteria or certain organisms from a pure strain. Its practical applications are concerned with the preparation of antigens, the diagnosis of certain diseases and its use in research bacteriology.

Plating technique as referred to in this paper is used to count viable cells in samples such as milk or broth cultures. Its practical application concerns its use in the milk industries or in problems such as the study of growth curves where a great many counts must be made.

Both procedures as they stand at the present time allow too great a personal factor to be consistent. Furthermore they do not conform close enough to mechanistic principles to permit their easiest manipulation in routine tasks. With these ideas in mind an effort has been made

to reduce the personal factor to a minimum by completely mechanizing the steps involved and making their application automatic wherever possible. As in all biological problems there are certain physiological factors concerned with the cells which cannot be mechanized but differences resulting from such factors can be decreased to a certain extent by automatically controlling their manipulation so that every step of the procedure is repeated in exactly the same way.

MECHANIZATION OF SINGLE CELL CULTURE

This technique of selecting single bacterial cells from a culture by means of micro-pipettes of glass was invented by Barber, 1904. Since its introduction it has become an important accessory in research bacteriology and has remained, up to the present time, practically unchanged. The need for specialization and its more complete mechanization is apparent from its somewhat limited use in problems where it could be used to advantage and in many semi-mechanical modifications introduced to simplify the method. Objections to the technique as it exists and is practiced at present might be summed up as follows:

1. It is not adaptable to mass work where many hundreds of isolations must be made.
2. It is difficult to make satisfactory micro-pipettes by hand.
3. It is difficult to change pipettes and to mount them in the manipulator.
4. It is difficult to prepare a satisfactory isolation surface.
5. The isolation droplet ordinarily formed on a grease film does not allow for the best definition of the isolated cells and once made are difficult to prevent from spreading beyond the confines of the field.
6. Only a low percentage of the isolated cells will grow.
7. There is no adequate control of physical conditions of moisture, temperature and the like, under which the cells are isolated.

Overcoming these difficulties involves a strict attention to details, and the design of special apparatus which can be worked without a great deal of technical ability on the part of the operator. The method and apparatus designed to mechanize single cell methods are described in a series of articles now in the hands of the editors of the *Journal of Bacteriology*. The apparatus and methods employed consist of:

1. An automatic mechanical pipette puller which makes mechanically perfect pipettes and requires no special skill or attention on the part of the operator.
2. A new and easy way of mounting and changing micro-pipettes.
3. A new type of isolation surface and automatic isolation droplet former. The isolation droplets made by this method and with this apparatus have the advantage of being flat with mechanically limited edges so that a definite area can be searched and the best possible visual conditions are obtained. Hundreds of isolation droplets containing bacterial cells can be made at once and in a routine manner.
4. A micro-manipulator, the action of which is initiated by checked levers which require a push to operate. This apparatus possesses the added advantage of being enclosed at all times and is heated electrically

to a constant temperature thus insuring constant moisture conditions as well as temperature conditions.

5. A new type of micro suction and injection apparatus which uses no pushers other than air and which can be accurately controlled with a button.

By facilitating manipulation and decreasing the time which it takes to isolate single cells much of the objection to low percentages of growth from single isolated cells should be eliminated. With completely mechanized and specialized apparatus the use of single cell technique is not difficult and requires no special skill. It is hoped that by simplifying the method it will be used with less hesitation.

MECHANIZATION OF PLATING TECHNIQUE AS IT APPLIES TO COUNTING VIABLE BACTERIAL CELLS IN A SAMPLE

It is generally agreed by investigators familiar with plating as a means of counting viable bacteria that the personal factor together with inadequate apparatus is responsible for the wide degree of error in successive bacterial counts from the same sample. On the other hand it is generally agreed that the plating method is the most acceptable and reliable way of estimating viable bacteria and that it is basically sound. Assuming then that plating contaminated samples on a nutrient surface is basically sound, efforts have been made to mechanize the steps of the procedure and to make them more uniform.

An examination of the source of error in the technique as it stands at present shows that it lies in these factors:

1. Making exact dilutions of the sample.
2. Delivering a certain amount of the diluted sample to the nutrient medium.
3. Bacterial cells when plated out in melted agar are trapped at all levels. Some cells will not develop as deep colonies. Those colonies which are deep are difficult to count.
4. The methods at present are too time consuming and this also allows for a certain degree of error.
5. The degree of skill and the exact care involved in the most accurate work is not possessed by the average worker nor is it always possible to exercise care in the press of routine requirements.

Many investigators have devised means of eliminating these errors. Surface plating methods have been devised, roll tubes used and various physical or chemical principles employed. These modifications have been more or less unsatisfactory because of the failure to mechanize the procedure properly and so adapt it to routine. Plating technique has been mechanized with a corresponding reduction in the personal equation and an increase in accuracy in the following way:

1. By designating an automatic dilution pipette which measures the sample automatically and allows further dilution to be made in the same pipette. It is desirable to have this dilution pipette correspond quite closely in use to the pipettes in use at present.
2. By using a motor driven turn table to turn a petri dish of hardened agar.

3. By spreading the culture with a special device which compensates for the unevenness of the plating surface and which deposits the cells separately on the isolation surface in regular formation. Every cell can be removed from the spreader permitting the use of small quantities of the diluted sample.

4. By using a new type of counting apparatus which eliminates eye strain and allows all cells on the plate to be counted with little effort.

Comparative results have justified the use of this new technique. A description of the methods and the apparatus is being prepared at this writing and will be submitted to the editors of the *Journal of Bacteriology* in the near future. The apparatus used in the mechanization of single cell culture and plating may be seen in my laboratories.

SUMMARY

It is believed that by applying mechanical principles to certain bacteriological methods it is possible to simplify the technique and make for greater accuracy in the final results. This paper presents a consideration of the necessary factors concerned with mechanizing single cell culture and plating. Apparatus has been designed, constructed and used to obtain this mechanization. Comparative results obtained by the use of the apparatus have shown the soundness of the methods.

REFERENCES

Reyniers, J. Arthur. Studies in Micrurgical Technique:

I. Routine Single Cell Isolation of Bacteria.

II. A Specialized Single Cell Isolator for Use in Bacteriology.

III. An Apparatus for Mechanically Constructing Glass Micropipettes.

IV. The Technique of Routine Single Cell Isolation and Culture. *Journal of Bacteriology*, Vol. 25, 1933.

V. A Moist Chamber for Tissue Culture and Cellular Dissection, p. 295.

VI. A Micro Suction and Injection Apparatus, p. 307, *Anatomical Record*, Vol. 56, 1933. No. 3.

THE ISOLATION OF ANAEROBIC CELLULOSE-DECOMPOSING BACTERIA FROM VARIOUS SOURCES

W. L. Weis, Purdue University

The destruction of cellulose by microbic life has attracted the attention of workers in this field for many years. Cellulose is found in various forms of purity in nature. In its natural form, it is extremely resistant to most chemical and biological action. This fact has made this field of research a difficult one to study and has centered the attention of bacteriologists on methods of attack. Because of the commercial importance of the anaerobic fermentations, much more work has been done along these lines.

This paper deals with the development and growth of crude cultures of cellulose-fermenting organisms from many different sources. The first medium used was modified from that described by Khouvine with the addition of 2 per cent cellulose. To make this medium solid 0.8 per cent agar was added.

Liquid Media

Di-potassium phosphate (K_2HPO_4) 5.0 grams, potassium nitrate (KNO_3) 2.5 grams, peptone 1.0 gram, sodium chloride (NaCl) 0.5 gram, cellulose 20.0 grams, calcium carbonate ($CaCO_3$) 10.0 grams, water (H_2O) 1000.0 cc.

Solid Media

Di-potassium phosphate (K_2HPO_4) 5.0 grams, potassium nitrate (KNO_3) 2.5 grams, peptone 1.0 gram, sodium chloride (NaCl) 0.5 gram, cellulose 20.0 grams, agar agar 8.0 grams, water (H_2O) 1000.0 cc.

The culture medium was autoclaved for 3 hours at 15 pounds pressure and cooled before inoculation. The liquid medium was placed in litre Erlenmeyer flasks or in 12 inch culture tubes. The tubes were inoculated with the material and covered with liquid paraffine oil to insure anaerobic conditions. The flasks of medium were inoculated and the mouth covered with lead foil to prevent evaporation and help insure anaerobiosis. In the case of the flasks the anaerobic condition was dependent upon the production of carbon dioxide which would exclude the oxygen present.

The presence of anaerobic cellulose fermenting bacteria in muck soil, feces, rotten wood, and the stomach of certain insects is easily demonstrated. The decomposition of cellulose by anaerobic bacteria is readily noted by the presence of the characteristic yellow color of the reaction. The samples to be tested are collected and placed in separate bottles. About five grams of a sample is placed in tubes containing about 30 cc. of the liquid media and incubated at room temperature, and at 37°C. for ten days.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

TABLE 1. Effect of temperature in relation to amount of growth

SOURCE	TEMPERATURE		SOURCE	TEMPERATURE	
	25-28°C.	37°C.		25-28°C.	37°C.
Rotten wood	+	++	Zebra feces	+	++
Muck soil	+	++	Rat feces	+	++
Horse feces	+	++	Llama feces	—	++
Hog feces	+	++	Buffalo feces	—	++
Goat feces	+	++	Woodchuck feces	+	+
Sheep feces	+	++	Skunk feces	+	+
Rabbit feces	—	++	Mice feces	+	++
Deer feces	—	++	Termite feces	+	++
Elk feces	—	++	Termite stomach	+	++
Elephant feces	—	+	Wood borer	—	+

— No growth, + slow growth, ++ rapid growth.

Table I shows that the best results were obtained from those organisms grown on this type of medium at 37°C. From this table it may be concluded that cellulose-fermenting organisms and especially the anaerobic spore formers are widely distributed in nature, and no doubt they play a very important role. A further study of the role of these organisms should reveal very interesting data in connection with the digestion of cellulose in the intestinal tract of the animal concerned.

Isolation. The attempts to effect an isolation of each culture was first made by preliminary enrichment of the culture. This method increased the cellulose-fermenting organisms, but did not entirely eliminate the contaminants. Some workers were able to eliminate these by repeated transfers and heating. This method was tried, but with little success. The dilution method was used, but the results were unsuccessful since all the tubes had the contaminants growing with the cellulose-fermenting organisms.

Attempts then were made to grow the culture on a solid medium. Such media as an agar starch solution proved useless, as also did beef extract and agar, and peptone and agar. Attempts then were made with a medium using cellulose as one of the constituents. The methods used by Winogradsky, Khouvine, and Cowles and Rettger were unsatisfactory for these organisms. A method was devised to use cellulose ground to a very fine state and mixed with agar and the basal salt solution. The cellulose was ground in the ball mill in a water solution. This type of ground cellulose is free from salts and acids, and is very cheap to make.

The method used for anaerobic conditions was to inoculate the cellulose agar and pour it in the plates and let it become solid, then cover the agar with sterile vaseline at 60° C. and let it harden. This method proved to be an easy and suitable anaerobic one.

In the early work on isolation from this cellulose agar, colonies appeared in 10 to 15 days on the vaseline plates. These colonies of cellulose-fermenting organisms could be easily detected on the medium by the appearance of a clear zone in the cellulose agar. These spots have been known as the "halo" or "enzymatic rings." When the colonies

are examined with the microscope the agar is found to be free of cellulose fibers.

According to theory these colonies could be easily picked and a pure culture obtained, but it was not found to be the case. In many of the cultures the colonies which were picked grew in a feeble manner and in a few transfers the new culture would die or fail to grow. After working with several kinds of media, it was found that there was a deficiency in one food in this medium which caused these organisms to fail to grow after picking and transfering them to a new culture.[1] In all the new cultures that were picked, contamination was always present, although there were never more than 2 or 3 types present. With the aid of the above method the cultures were enriched into a semi-pure state containing 2 or 3 different types of organisms.

Morphology. In these purified cultures there was more than one type of organism present. The vegetative cells in the liquid medium were of several types. The cells ranged from a short slender rod about 0.3 micron in diameter and from 6 to 8 microns in length, to types which were oval in shape, about 0.4 micron in diameter and 1 to 4 microns in length. The different types occurred singly and in chains of 2 to 6 each. Some were curved in shape. In all cases the organisms formed spores. The spores were formed either on the middle of the rod or at the end. They stained readily with all the common dyes. The gram reaction stain is uncertain, but as a rule the cells seem to be gram positive. The organisms in all the cultures seem to be motile in the hanging drop.

REFERENCES

1. Bradley, L. A. and Rettger, L. F. Studies on aerobic Bacteria commonly concerned in the decomposition of cellulose, Jour. Bact., **13**:321-345, 1926.

2. Cowles, P. B., and Rettger, L. F. Isolation and study of an apparently widespread cellulose fermenting anaerobe. Cl. Cellulosovens (n. sp.?) Jour. Bact. **21**:167-182, 1931.

3. Khouvine, Mme. Y. Un anaerobic de l'intestin humain digerant la cellulose, Compt. Rend. Soc. Biol. **87**:922-923, 1922.

4. Khouvine, Mme. Y. Digestion de la cellulose par la flore intestinal de l'homme, Ann. Inst, Pasteur **37**:711-752, 1923.

5. Winogradsky, S. Sur la degradation de la cellulose dans la sol. Ann. Inst. Past. **43**:549, 1929.

6. Winogradsky, S. Recherches sur le degradation de la cellulose dans le sol. Compt. Rend. Acad. Sci. (Paris) **184**:493-497, 1927.

[1] Author's unpublished thesis—"The Decomposition of Cellulose by Bacteria Isolated from Intestinal Tract of Termites," which is in the university library.

SOME ALGAE OF THE LOWER WABASH VALLEY

M. E. BRITTON and B. H. SMITH, Indiana State Teachers College

This paper is a preliminary report of the algae of the Lower Wabash Valley and, at the present, includes a partial report from Sullivan, Clay, Vigo, Vermillion, Parke and Knox counties.

The collections were made by the writers during the months of July, August, September and October of 1932, the material being, in most cases, immediately preserved in a 6-3-1 solution of water, alcohol and formaldehyde. This solution seems to cause a minimum of distortion to the cell walls and contents.

We are reporting a total of thirty-nine species, varieties and forms. Of these, one genus, five species, five varieties, and one form have not been previously reported from the state, and the others here reported are new for the counties listed. The writers hope to extend this work during the coming year so as to cover the extreme southwestern counties of the state.

As a matter of simplicity, we are omitting the technical classification of the algae, and listing them simply in alphabetical order.

LIST OF ALGAE

[3]*Aphanocapsa pulchra* (Kuetzing) Rabenhorst. Parke Co., July 4, 1932. [4]*Chrococcus minutus* (Kuetzing) Naegeli. Parke Co., September 14, 1932. [4]*Closterium acerosum* (Schrank) Ehrenberg. Vigo Co., October 1, 1932. [4]*Closterium acerosum* (Schrank) Ehrenberg. *var. elongatum.* Bréb. Vermillion Co., September 14, 1932; Vigo Co., October 1, 1932. [4]*Coelastrum cambricum* Archer. Sullivan Co., July 4, 1932. [4]*Coelastrum microporum* Naegeli. Sullivan Co., July 4, 1932. [4]*Desmidium aptogonium.* De Brébisson. Sullivan Co., July 4, 1932; Vigo Co., August 28, 1932. [4]*Dictyosphaerium ehrenbergianum* Naegeli. Sullivan Co., July 4, 1932. [4]*Dictyosphaerium pulchellum* Wood. Sullivan Co., July 4, 1932. [1]*Dimorphococcus lunatus* A. Braun. Sullivan Co., July 4, 1932. [2]*Euastrum verrucosum* Ehrenb. *var. reductum,* Nordst. Vigo Co., October 1, 1932. [1]*Gomphosphaeria lacustris* Chodat. Vigo Co., October 16, 1932. [4]*Hyalotheca mucosa* (Dillwyn) Ehrenberg. Sullivan Co., July 4, 1932. [4]*Kirchneriella obesa* (W. West) Schmidle. Sullivan Co., July 5, 1932. [4]*Micrasterias americana* (Ehrenberg) Ralfs. Sullivan Co., July 4, 1932. [4]*Micrasterias truncata* (Corda) De Brébisson. Sullivan Co., July 4, 1932. [4]*Nephrocytium agardhianum* Naegeli. Sullivan Co., July 4, 1932. [4]*Oedogonium borisianum* (LeClerc) Wittrock. Sullivan Co., July 4, 1932. [2]*Oedogonium crassum* (Hassall) Wittrock. *var. longum* Transeau. Sul-

[1] Species not previously reported from state.
[2] Variety or forms not previously reported from state.
[3] Genus not previously reported from state.
[4] Genus or species not previously reported from county.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

livan Co., July 4, 1932. [2]*Oedogonium crenulatocostatum* Wittrock. *form cylindricum*. Hirn. Clay Co., September 8, 1932. The longitudinal ribs of the oospore vary from crenulate to dentate. [1]*Oedogonium gunnii* Wittrock. Vigo Co., August 28, 1932. No antheridia were found. Oogonia 1-6 seriate. [3]*Oedogonium kurzii* Zeller. Sullivan Co., September 7, 1932. [2]*Oedogonium macrandrium* Wittrock. *var. propinquum* (Wittrock) Hirn. Vigo Co., August 28, 1932. [4]*Oedogonium plagiostomum* Wittrock. *var. gracilius*, Wittrock. Sullivan Co., July 5, 1932. Smaller than measurements given by Tiffany. [4]*Oedogonium sexangulare* Cleve. Sullivan Co., July 4, 1932. [3]*Onychonema filiforme* (Ehrenberg) Ray and Bissett. Sullivan Co., July 4, 1932. [2]*Onychonema laeve* Nordstedt *var. latum*, W. and G. S. West. Sullivan Co., July 4, 1932. [4]*Pediastrum duplex* Meyen. *var. clathratum* (A. Brown) Lagerheim. Sullivan Co., July 4, 1932. [4]*Pediastrum duplex* Meyen. *var. cohaerens*, Bahlin. Vigo Co., October 1, 1932. [4]*Pediastrum tetras* (Ehrenberg) Ralfs. Sullivan Co., July 4, 1932. [4]*Pleurotaenium maximum* (Reinsch) Lund. Vigo Co., August 28, 1932; Clay Co., September 8, 1932. [4]*Scenedesmus abundans* (Kirchner) Chodat. *var. longicauda*. G. M. Smith. Vigo Co., October 16, 1932. [4]*Scenedesmus arcuatus* Lemmermann. Vigo Co., September 15, 1932. [4]*Scenedesmus obliquus* (Turpin) Kuetzing. Vigo Co., October 16, 1932. [4]*Scenedesmus quadricauda* (Turpin) De Brébisson. *var. westii*. G. M. Smith. Vigo Co., August 28, 1932. [1]*Sorastrum americanum* (Bahlin) Schmidle. Sullivan Co., July 4, 1932. [4]*Spirogyra decimina* (Mueller) Kuetzing. Sullivan Co., September 14, 1932. [4]*Volvox globator* L. Sullivan Co., September 14, 1932. [4]*Volvox mononae* G. M. Smith. Sullivan Co., July 4, 1932. [4]*Westella botryoides* (W. West) De Wildeman. Vigo Co., October 1, 1932.

BIBLIOGRAPHY OF INDIANA RECORDS FOR COUNTIES MENTIONED

1. Andrews, F. M. 1926—A List of Algae of Monroe County, Indiana. II. Proc. Ind. Acad. Sci., **36**.

2. ——— 1929—Algae of Monroe County, Indiana. III. Proc. Ind. Acad. Sci., **39**.

3. Palmer, C. Mervin. 1929—Algae of Indiana—a classified check list of those published between 1875 and 1928. Proc. Ind. Acad. Sci., **38**:109-121.

4. ——— 1932—Plankton Algae of White River in Marion County and Morgan County, Indiana. Butler University Botanical Studies, Vol. II, No. 10.

5. White, Helen L. 1930—The Phytoplankton of a Solution Pond With Special Reference to the Periodicity of Certain Algae. Proc. Ind. Acad. Sci., **40**.

PLANTS NEW OR RARE TO INDIANA, XVIII

CHAS. C. DEAM, Bluffton, Indiana

Specimens of all of the species reported in this paper are in the Deam Herbarium. The determinations have been checked by specialists.

Thelypteris spinulosa var. *fructuosa* (Gilbert) Fernald. Lagrange County, September 7, 1931, No. 51,032. In a thick, low woods on the George Dutter farm about 4 miles east of Mongo.

Equisetum trachyodon R. Br. Steuben County, September 22, 1931, No. 51,103. Frequent on the low, sandy border of the east side of Lake James, in Pokagon State Park. Determined by J. H. Schaffner.

Lycopodium lucidulum var. *occidentale* (Clute) Wilson. Fountain County, April 22, 1917, No. 22,543. In a moist habitat in moss, near the base of a sandstone ledge on a north slope of Bear Creek near Fountain. Closely associated with *Mitchella repens* and *Polypodium virginianum*. Montgomery County, May 19, 1887, at the "Shades," collected by W. S. Blatchley. Determined by L. R. Wilson.

Lycopodium Selago var. *patens* (Beauv.) Desv. (*Lycopodium lucidulum* var. *porophilum* Lloyd & Underw. of the Indiana flora.) Crawford County, April 20, 1911, No. 7,895. In pockets of the cliffs in the deep ravines about 1 mile east of Tasweli; June 8, 1919, in pockets of the cliffs at "Evergreen Bluffs" about 4 miles southwest of Grantsburg; and June 18, 1927, on a ledge of rock at the base of a cliff along Turkey Creek about 3 miles west of Fredonia. Martin County, in pockets of the cliff along White River about a mile north of Shoals. Determined by L. R. Wilson.

Festuca octoflora Walt. This species has been studied and a variety of it has been described by Fernald (Rhodora 34:209-211. 1932). The typical form of the species is found from southern New Jersey to Florida, westward to Texas, and northward to Oklahoma and Indiana. I have specimens from Daviess, Gibson, Knox, Martin, Posey, and Spencer counties.

Festuca octoflora var. *tenella* (Willd.) Fern. This variety ranges from southern Maine, southwestern Quebec to British Columbia and southward to Arkansas, Texas, and California. I have this variety from Allen, Brown, Cass, Clark, Clay, Crawford, Elkhart, Floyd, Harrison, Jackson, Jasper, Kosciusko, Lagrange, Lake, Laporte, Newton, Perry, Pike, Porter, Pulaski, St. Joseph, Steuben, Sullivan, Warren, Washington, and White counties.

POA TRIVIALIS L. This European grass has been reported for Carroll, Floyd, and Marion counties, but we have no specimens from these counties. Cass County, June 5, 1931, No. 50,201. Growing near the water on the muddy, west bank about 50 feet from the mouth of the small creek which empties into Pipe Creek near the bridge at Pipe Creek Falls.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

Panicum Tuckermani Fernald. Cass County, September 28, 1931, No. 51,234. Frequent in a dried up bayou on the southwest side of Lake Cicott.

Lemna cyclostasa (Ell.) Chev. Noble County, July 13, 1931, No. 50,405. In the mill race at Wilmot. Determined by L. E. Hicks.

X Quercus Scheuttei Trel. Lawrence County, June 5, 1932, No. 53,522. A tree in the Salt Creek bottoms about 2.5 miles northwest of Bedford. Collected by Ralph M. Kriebel of Bedford, who kindly permitted me to make this report.

SILENE CSEREI Baumg. Montgomery County, June 5, 1932, No. 52,038. Frequent for a distance of about 50 feet in the ballast of the Monon Railroad about 2 miles south of Linden.

Rosa pimpinellifolia L. Montgomery County, May 19, 1932. No. 51,788. A large colony along the Monon Railroad about 1⅛ miles south of Ladoga. The colony is far removed from any present habitation and seems to be spontaneous and spreading.

Hibiscus palustris L. This species in southern Indiana has, no doubt, been confused with *Hibiscus Moscheutus* L. It is an inhabitant of low ground and is often surrounded by pin oak, and grows with buttonbush. I have not seen it growing with *Hibiscus militaris*. I have it from Clark, Daviess, Dubois, Greene, Harrison, Knox, Posey, Spencer, Sullivan, Vanderburgh, and Vigo counties.

Polygala Pretzii Pennell. This is a segregate from *Polygala verticillata*. I have it from Allen, DeKalb, Lagrange, Noble, Steuben, and Whitley counties.

Polygala verticillata var. *sphenostachya* Pennell. This is another segregate from *Polygala verticillata*. Newton County, August 30, 1916, No. 21,512. Sandy roadside cut 4.5 miles north and 1.5 miles west of Morocco. Determined by F. W. Pennell.

Sabatia gracilis (Michx.) Salisb. (*Sabbatia campanulata* (L.) Torr.) Daviess County, August 13, 1932. No. 52,742. One large colony at the south side of a low, sandy flat in the Herschel Green woods about 4 miles north of Washington. This plant is usually found in the southeastern part of the United States, but was found growing here with other plants of that area. Some of them are *Rhexia mariana*, *Gaura filipes*, *Hibiscus palustris*, and others.

Dracocephalum speciosum Sweet. This species has not until recently been separated from *Dracocephalum virginianum*. I have it from Adams, Allen, Hamilton, Huntington, Knox, Lake, Marion, Newton, Randolph, Sullivan, and Wells counties.

Dracocephalum virginianum L. Since this species was an aggregate, it is of interest to know the range of this species after the preceding one has been taken from it. I have specimens from Benton, Cass, Clark, Decatur, Fulton, Gibson, Henry, Jasper, Kosciusko, Lawrence, Marshall, Perry, Porter, Posey, Pulaski, Ripley, Starke, Tippecanoe, Tipton, Warren, Wayne, and White.

Stachys Clingmani Small. I have this species from Brown, Clark, and Jennings counties. Determined by Carl Epling.

Stachys hispida Pursh. Clinton County, July 21, 1915, No. 17,642. Roadside 3 miles south of Frankfort. Determined by Carl Epling.

Physalis nyctaginea Dunal. Monroe County, July 4, 1932, No. 38,963. In a shady black and white oak woods about 4 miles east of Bloomington.

Lobelia spicata var. *hirtella* Gray. Lagrange County, July 7, 1920, No. 31,317. Common on the sandy flood plain of Pigeon River 1 mile northwest of Scott. Noble County, July 5, 1920, No. 31,252. Low, marl border of Eagle Lake.

MEASUREMENT OF PLANT GROWTH BY MEANS OF THE OPTICAL LEVER

Raymond E. Girton, Purdue University

Introduction

The use of the optical lever principle for measuring small movements has been applied to plant experimentation, so far as indicated by published work, by relatively few persons. Bose[1] (1906) used the optical lever for measuring slight movements in plants. Miss Delf[2] (1916) employed an optical lever apparatus designed by Dr. F. F. Blackman for measuring minute movements in tissues associated with turgor changes. Very recently Wadsworth[3] (1932) has described a form of optical lever which has been used in certain sugar cane investigations.

Two simple forms of the optical lever have been constructed and used by the author for demonstrating and measuring growth in plants. Because of the simplicity of design and cheapness of construction, it has been thought advisable to publish a brief description of these instruments.

Description of the Apparatus

Figure 1-A illustrates the assembly of the apparatus as employed for making quantitative measurements on the growth of plants. A mirror (c) having a horizontal scratch in the middle of the silver backing is mounted on an axis coinciding with this scratch. The mirror is rotated on this horizontal axis by means of a short lever arm attached to the center of the back of the mirror. A cord-wire system connects the lever arm to the growing plant (i). The mirror is firmly supported by a clamp and ring stand with the potted plant resting upon the base of the ring stand (h_1).

A second ring stand (h_2) supports an inverted meter stick (l) to which is attached a piece of cardboard (j). This cardboard stop is perforated by a single hole which serves as a sighting aperture. The cardboard stop is attached to the meter stick by a rubber band in such a way as to allow the stop to be moved to any desired position on the meter stick.

When an experiment is to be conducted, the apparatus is set up on a firm base with the sighting aperture adjusted to a height equal to that of the mirror axis. If the eye is placed at the sighting aperture, a portion of the scale can be seen reflected in the mirror. The scale reading coinciding with the reference line scratched on the mirror is then re-

[1] Bose, J. C., 1906: Plant Response.

[2] Delf, E. Marion, 1916: Studies of protoplasmic permeability by measurement of rate of shrinkage of turgid tissues. I, influence of temperature on the permeability of protoplasm to water, Ann. Bot., **30**:283-310.

[3] Wadsworth. H. A., 1932: The optical lever as a tool in physiological studies, Plant Physiol., **7**:727-731.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

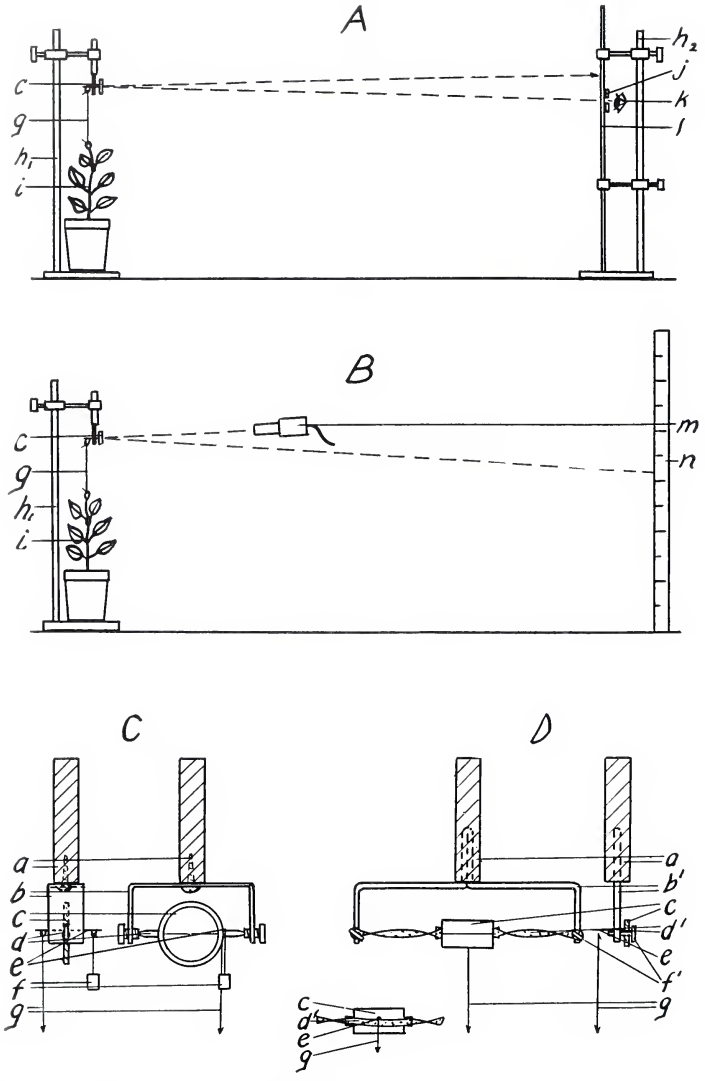


Fig. 1. Optical lever apparatus. (a) wooden handle, (b) metal frame, (b) heavy wire frame, (c) mirror, (d) mirror axis, (d) rubber band, (e) lever arm, (f) counter balance weight, (f) adjusting peg, (g) connecting cord leading to plant, (h_1) and (h_2) ring stands, (i) plant, (j) card board light stop with sighting aperture, (k) eye, (l) meter stick, (m) light source, and (n) large scale.

A—Apparatus set up for quantitative measurement.

B—Apparatus set up for lecture demonstration.

C—Pivot type of mirror detail.

D—Torsion type of mirror detail.

corded at intervals as an index of the growth of the plant. As the plant increases in length the mirror is rotated forward and the line of vision passes down the scale with double the rapidity of a material lever of the same dimensions. For small angles of rotation a straight meter scale may be employed without introducing serious error in the determination of the actual growth of the plant. When large angles are encountered, a curved scale greatly reduces the degree of error. (See Wadsworth, loc. cit.)

Modifications of the foregoing set up may include the substitution of a small telescope for the sighting aperture, or the use of a concentrated light beam and reflected spot of light as indicated in figure 1-B. This latter form of the apparatus is of particular value for lecture or other demonstrations, since very large magnifications can be secured and since the moving spot of light may be easily seen by a group.

Detailed views of the two different types of mirrors used are given in figures 1-C and 1-D. Figure 1-C represents the pivot form of the device, consisting of a small mirror (c) attached to a metal axis (d) pointed at each end. These metal points turn in metal bearings, which are supported by a metal and wood frame (b, a). Two short lever arms (e) fixed at right angles to the main axis serve for connecting the mirror with the plant (rear lever arm) and with the counterbalance weight (forward lever arm). A weight (f) is required of size sufficient to maintain a slight tension on the plant and to keep the connecting cord (g) taut.

The second type of mirror is illustrated by figure 1-D. In this type a twisted rubber band (d^1) is substituted for the horizontal metal axis. The rotation of the mirror (c) is secured by the torsion force of the rubber band. The magnitude of this force, and consequently the amount of tension exerted upon the plant, can be varied by the number of backward twists previously given the rubber band, and by the degree of tension placed upon the elastic band by the pegs (f^1). Different degrees of tension upon the plant can also be effected by the use of rubber bands of varied sizes. A small rubber band which, when broken in two, gave a tension upon the plant of 0.2 to 0.4 gm. was used for the experiments herein recorded. The rubber band is not permanently fastened to the mirror but is simply slipped through two wire loops cemented to the back of the mirror as indicated in the figure (Fig. 1-D). The mirror is mounted in a frame of heavy wire possessing sufficient rigidity to resist bending (b^1).

Illustrative Experiments

The results of certain experiments designed to demonstrate the use of the apparatus are given in figure 2. Potted bean and pea plants were employed, using both the pivot and the torsion types of mirror, and varied environmental conditions. All of the experiments were carried out in the greenhouse under conditions of natural winter illumination.

A short experiment was performed with a potted bean plant of about 25 cm. height under dull light conditions on a cloudy day (Fig. 2-A). The air temperature was maintained at approximately 19° C. The curve (b) of the same graph represents readings taken from another

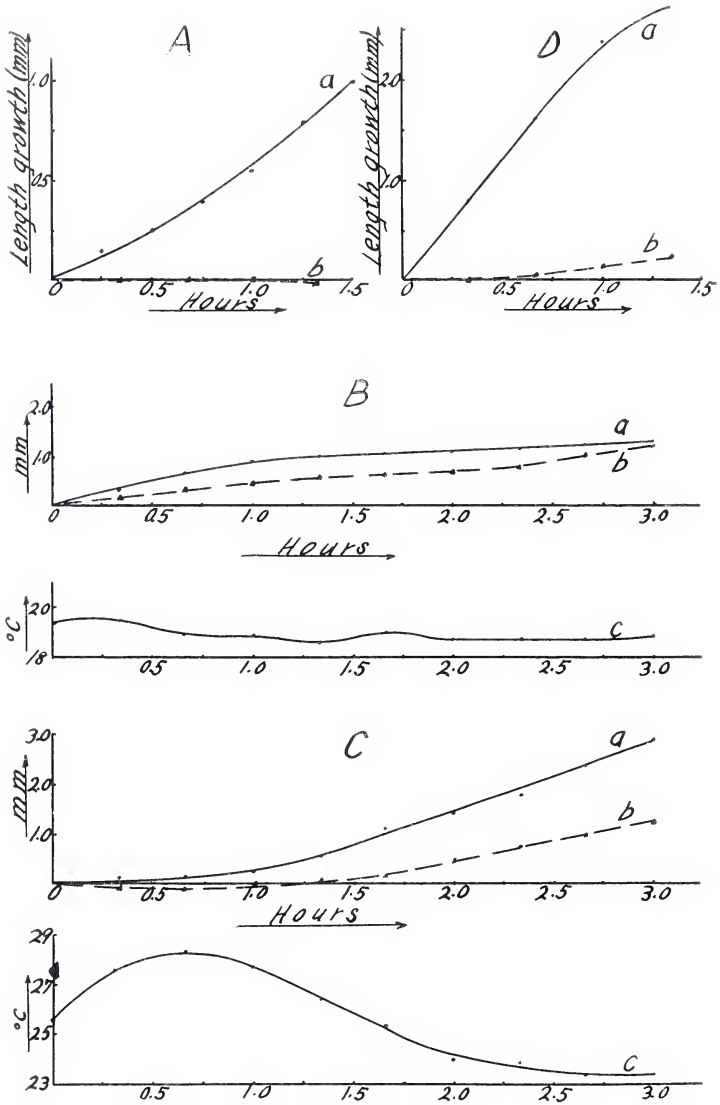


Fig. 2.

Fig. 2. A—Growth curves for a young bean plant and a control. a = plotted data for the young bean plant. b = plotted data for the control with the connecting cord anchored to the pot instead of fastened to a plant. Data obtained with the pivot type of mirror.

B—Growth curves for young pea seedlings. a = plant 3.5 cm. high. b = plant 4 cm. high. c = air-temperature curve.

C—Growth curves for bean plants. a = plant 30 cm. high. b = plant 33 cm. high. c = air-temperature curve.

D—Growth curves for irrigated and unirrigated bean plants. a = irrigated plant. b = unirrigated plant. Data for graphs B, C, and D were obtained with the torsion type of mirror.

experiment upon a dummy plant in order to discover whether any incidental changes in length of the braided silk connecting cord were sufficient to introduce appreciable error. An examination of this figure shows that such changes are evidently slight. This conclusion was substantiated by an experiment conducted for six hours with a similar result.

Two sets of duplicate curves are shown in figures 2-B and 2-C together with curves representing the prevailing air temperatures. It is evident that the growth in length of similar pea or bean plant does not take place at identical rates under the same environmental conditions, but that the forms of the individual growth curves are much alike. The curves shown in figure 2-C are of especial interest since they show slight or negative growth at high temperatures, accompanied by high light intensities, and more rapid growth with falling temperature and a lower light intensity.

A further experiment (Fig. 2-D) was conducted in order to demonstrate the relation of plant growth and the available soil moisture supply. Two similar potted bean plants growing in soil with a dry appearance were chosen. One pot was set in a pan of water and subirrigated for 10 minutes. The soil of the second pot was allowed to remain dry. This soil was not dry enough, however, to cause the plant to show signs of wilting. Growth records taken over a short period of time demonstrate an extremely rapid growth rate for the irrigated plant (a) as contrasted with the very slow rate for the unirrigated plant (b).

Concluding Remarks

The apparatus herein described has proved useful for both demonstrating and measuring length growth in plants. If proper precautions are taken in carrying out the experiments to avoid (1) excessive tension and injury to the plant, (2) heliotropic curvatures due to uneven illumination, (3) strong air currents, and (4) changes in the length of the connecting cord (oiled braided silk cord is recommended), satisfactory results may be obtained under a variety of environmental conditions.

SOME EFFECTS OF LIGHTNING ON TOMATO PLANTS

STACY HAWKINS, Florida Agricultural Experiment Station

On September 29, 1932, a furious thunderstorm passed over the Sub-Tropical Experiment Station near Homestead, Florida. Five days later the writer's attention was called to a field about a mile west of the Station in which there was an elliptical area of dead tomato plants. The cause of the trouble was ascribed by the owner, Mr. Morris White, to lightning and this was vouched for by negro laborers who were sitting in an automobile during the storm within a few rods of where the lightning struck.

The field in which the plants were set was a five-acre plot surrounded on two sides by a citrus grove, on one side by pine woods, and on the remaining side by an asphalt road. The characteristics of the "soil," as it might be called, are different from those to be found in most any other locality in the United States. The virgin "soil" is a porous conglomerate limestone of the Miami series that outcrops in all the "pinelands" south of Miami, Florida. As is the common practice in this locality, the limestone, which is quite fragile, had been scarified and made tillable by combining the rock fragments with the red clay soil (Fig. 1) found in the pockets and interstices of the limestone.

Fig. 1. A tomato plant struck by lightning in which the injured central portion of the stem is ribbed and free of leaves and suckers, while suckers developed at each node below and above the injured portion. Note rocky soil. Photographed November 19, 1932, by W. M. Fifield.

At the time the writer first visited the field the plants in the affected area were being reset but examinations were made of the plants in the area along with a survey of the amount of damage done. It was found that the area in which the plants had been killed or damaged was somewhat elliptical in shape measuring 32 feet by 45 feet, with the greater

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

diameter parallel to the rows of tomato plants. Within the area 107 plants, set eighteen inches apart in the row, with a space of five feet between rows, had been killed or so badly damaged that they had to be reset. Regardless of the fact that there had been occasional heavy showers between the time the lightning struck and the time the writer first visited the field there was still unmistakable evidence, preserved by the rocky characteristics of the soil, that the lightning had struck in the center of the affected area. At this point there was a small jagged hole, about an inch and a half in diameter, bored into the limestone rock to a depth of eighteen inches. Extending three feet on either side of the hole and almost at right angles to the rows of plants was a U-shaped trough about six inches across and three inches deep. The rows of tomato plants extended east and west. It would seem from the conditions just stated that the direction which the lightning bolt may travel has nothing to do with its destructiveness as far as herbaceous plants set in rows is concerned for in this case, as already stated, and in another instance[1] the greater damage was in the direction of the rows of plants.

An examination of the plants in the affected area showed that conditions were similar to those reported by Brown and Gardner[2] in that "the plants at the center were killed and the severity of the injury became less towards the outer limits of the area. The interesting feature was that the plants showed, among other symptoms, typical "hollow-stem," a condition characterized by the collapse of the pith within the stem. At the time the writer first examined the tomato plants in the damaged area those plants nearest the center were dead above ground and the tap root of the plants had begun to turn brown and become slimy. The aerial parts of the stems that had died had completely collapsed to their tips and had become shriveled and prominently ribbed or angular, but that portion of the plant below ground had not shriveled even though cross sections of the tap root showed that the pith had collapsed to the tip. Examinations of plants located about half way between the center and outer edge of the affected area showed a somewhat different condition. At this distance, the plants, which were about twelve inches high at the time the lightning struck, had shriveled at the ground line or a little below to a point about half way up the stem. In these plants the distance that the pith had collapsed above and below the shriveled portions of the stems also decreased. The outside portion of the upper part of the stem appeared to be perfectly normal, although the plants were lying prostrate on the ground because the lower part of the stems could not support the tops. A comparison of cross sections of the stem from the shriveled portion of plants in the lightning-affected area with cross sections of corresponding portions of plants outside the damaged area showed a condition similar to that reported by Weber[1] for potatoes in that "the vascular bundles occupied very nearly the same amount of area in the injured stems as in the healthy ones, showing that this tissue suffered very little injury. This may account for the turgidness of the foliage of the prostrate plants."

[1] Weber, G. F. Lightning injury to potatoes. Phytopathology, 21:213-218. 1931.

[2] Brown, H. D., and Max W. Gardner, Lightning injury to tomatoes. Phytopathology, 13:147. 1923.

[1] Lit. Cited. 1931.

At the periphery of the area affected by the lightning the amount of damage to plants had decreased to such a degree that only a few of them were injured. Those that showed injury were only slightly ribbed over a short portion and, although the stems drooped somewhat in most cases, they were turgid enough to maintain a nearly upright position.

So far as the writer has been able to learn, no one has previously reported on any abnormality that might develop in those plants less seriously injured by lightning when allowed to continue growth. It was the privilege of the writer to observe from time to time the 34 injured plants left to grow around the outer edge of the affected area. These 34 plants, without exception, developed so abnormally that they could readily be distinguished from the undamaged plants in the remainder of the field. One strikingly noticeable characteristic of these plants was their squatty appearance. The main stems grew but a little taller than they were at the time the lightning struck but became bushy by the growth of an unusual number of short suckers on the stem. These suckers, in all cases where microscopic examinations were made, appeared to be perfectly normal in structure but were short and spindling. This condition came about, no doubt, from the fact so many of them developed on the stem.

One interesting fact noted in regard to the growth of suckers was that none of them originated in that part of the stem which showed injury indicated by the ribbed condition. In all instances the suckers grew either above the injured portion of the stem or below it near the ground line. (Fig. 1.) Another characteristic noted during the period of time these plants were observed was that practically all the injured plants shed their leaves in the injured area of the stem. In some cases where no, or very few, suckers started from the ground line the plant took on a peculiar appearance; there being nothing but the bare stem for some distance up the plant and then this was topped by a dense growth of leaves and short suckers. These plants might be said to have resembled somewhat an inverted featherduster stuck in the ground. Others of the injured plants that put out suckers from below the shriveled area assumed a more bushy appearance that might be compared to a low hedge plant.

One of the most striking things noted by the writer in his examinations from time to time was that the terminal bud in all the injured plants finally died. Without a single exception the plants, upon resuming growth, began its upward growth from the bud in the axis of the uppermost leaf. This would seem strange as none of the axillary buds, to all appearances, were damaged above or below the shriveled part of the stem yet the terminal bud of every injured plant was killed. In all probability the death of the terminal bud was one of the reasons why the plants suckered out and became so bushy.

Considered from the standpoint of productiveness the injured plants were worthless. During the entire season they produced but little fruit and none of commercial value. Most of the vines produced but few flowers and then shed the greater portion of these. The fruit that was set by these plants ripened so small that it had to be discarded as culls, although it appeared normal in other respects.

THE DEVELOPMENT AND STRUCTURE OF THE JUVENILE LEAVES IN *Marsilea quadrifolia* WITH NOTES ON THE ANATOMY OF THE STEM AND ADULT PETIOLE

RUTH V. HENDERSON, Indiana University[1]

Historical. Most of the literature on Marsilea is concerned with the development and structure of the spore fruit and on the gametophytes, but comparatively little has been written on the juvenile leaves.

Engler and Prantl (5) state that in the development of the sporophyte of Marsilea from the spore, there are four stages in the leaf development. First is the cotyledon; second, submerged primordial leaves which develop but a single blade having stomata on the upper side; third, floating leaves whose blades spread out upon the surface and develop stomata on the upper side; and fourth, foliage leaves borne in the air having stomata on both sides.

Bower (3) calls attention to six forms of juvenile leaves as figured by A. Braun. The sixth leaf in the figure is shown as having four lobes but the lobes are not disposed as the four lobes in the adult form. He states that the first juvenile leaf is subulate, those that follow are spatulate, then two lobed, and finally the four lobed leaf. Bower points out the form of venation in these leaves and especially the fact that the marginal loops by which the separate veins are linked, form a closed system.

Campbell (4) points out that the cotyledon grows for a time from the regular divisions of the primary octant cells and the subsequent growth is purely basal. The cotyledon is a slender, cylindrical leaf tapering to a fine point, where the cells are much elongated and almost colorless. Its growth is at first slow, but at a later period it begins to grow with great rapidity and soon reaches its full size. This is largely due to a simple elongation and expansion of cells.

Material and Methods. The plants upon which this work is based were grown in the laboratory from the spores. The sporocarps were sown in water in a glass jar and in a glazed earthen-ware vessel on June 18, 1931. An opening was made in the spore fruit to facilitate the penetration of water in order to cause, in a shorter time, the escape of the sori which are attached to the well-known gelatinous cord.

Both vessels contained one inch of rich soil, one inch of sand and about two inches of water. The glass jar was covered with a piece of glass during the experiment to prevent too rapid evaporation of the water. Both vessels remained outside on the ledge of a north window

[1] Submitted in partial fulfillment of the requirements for the degree, Master of Arts, in the Department of Botany in the Graduate School of Indiana University.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

of the laboratory. The temperature of the water in the glass jar varied from 2—5° C. higher than that in the earthen vessel.

Observations. The following data were obtained from plants growing in the glass jar because they grew much more rapidly than those in the earthen vessel.

There were seven juvenile leaves produced by the plants. The first juvenile leaf or cotyledon appeared June 21, 3 days after sowing. At first, the growth of the leaf was apical and later basal. The tip of the leaf which terminated in three, elongated, almost colorless cells, was slightly twisted. The leaf was mature June 26, 8 days after sowing, with a length of 14 mm. and a width of 1 mm. across the middle which is the widest part (Fig. 1, A).

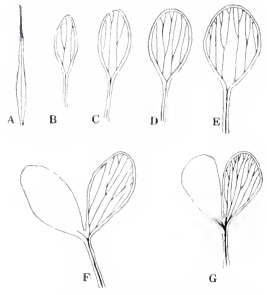


Fig. 1. *Marsilea quadrifolia*. The seven juvenile leaves in order from A to G.

This leaf produces one to three celled trichomes which are scattered over the under surface. Water and air stomata occur on both sides but more abundantly on the upper side. The water stomata are large and round due to the open pore, while the air stomata are slightly smaller and are usually closed. In the case of this first leaf, the water stomata occurs at the apex and when grown in air, a small drop of water is formed at the tip. A single vein extends from the base to near the extreme tip. The extremity of this vein consists of a row of single spiral tracheids.

The second juvenile leaf made its first visible appearance on June 24, 6 days after sowing. On June 26, this leaf was 4.5 mm. long and 1.33 mm. wide. The leaf was full grown on the 9th day, June 27, with a length of 7 mm. and a width of 2 mm. (Fig. 1, B).

The leaf blade is much shorter and broader than the cotyledon, and the petiole is almost as long as the blade which has 5-6 veins. These veins are closed or joined together along the margin which is the region where the water stomata occur.

The following juvenile leaves resemble the above leaf very closely. The difference consists in their increase in size and change in shape of the leaf blade. They all have trichomes and air and water stomata. The trichomes appear on the under side of the leaf, while the air stomata are found on the upper surface and are very few or lacking on the under surface.

The third juvenile leaf appeared June 26, 8 days after sowing. On June 27, this leaf was 8 mm. long and 2 mm. wide. The leaf was full grown June 28, when the plant was 10 days old, having a length of 10 mm. and a width of 4 mm. (Fig. 1, C). The leaf had 7-8 closed veins.

The fourth leaf appeared June 27, 9 days after sowing. On the 11th day the leaf was 7 mm. long and the leaf blade was 3 mm. wide. The leaf was full grown July 2, when the plant was 14 days old, having a length of 12 mm. and a width of 3 mm. The leaf blade and petiole are about the same length and the leaf has 10-12 veins (Fig. 1, D).

The fifth leaf appeared on June 30, 12 days after sowing. On the 14th day, the leaf was 10 mm. long and 4 mm. wide. It reached its full size July 3, 15 days after sowing, having a length of 15 mm. and a width of 5 mm. There were 15-17 veins in the leaf blade which was about as long as the petiole (Fig. 1, E).

The sixth leaf made its first visible appearance on July 2, 14 days after sowing. This leaf consisted of two blades. On the 16th day, the leaf was 11 mm. long and each blade was 3 mm. wide. The full size was reached on July 9, when the plant was 21 days old. It had a length of 16 mm. and a width of 3 mm. per blade (Fig. 1, F). The petiole is about one and one-half times as long as the blades. One blade had 14 veins and another 13, while on another plant each of the two blades had 13 veins.

The seventh and last juvenile leaf appeared July 6, when the plant was 18 days old. On the 23rd day, this leaf was 19 mm. long and each of the two blades were 4 mm. wide. The leaf was full grown July 15, 27 days after sowing, with a length of 22 mm. and each blade had a width of 5 mm. (Fig. 1, G). The petiole is almost twice as long as the blades. The leaf is circinate in the bud which is a characteristic of the adult leaves. In the case of one plant there were 21 veins in one blade and 25 in the other, and in another case there were 24 veins in each blade.

The first adult leaf (the eighth) appeared on July 7, 19 days after sowing. On July 11, the leaf was 41 mm. long and the blades were not unfolded. On July 21, when the plant was 33 days old, the leaf was 10.5 mm. long and each of the four blades was 9 mm. wide and 9 mm. long. During the development of the juvenile leaves, the stem remained very short, but began to elongate as the adult leaves were produced. The stem between the seventh and first adult leaf was 1 mm. long, between the first and second adult leaf 2 mm., and between the second and third 3 mm. as shown in table 2.

Adult Leaf. Engler and Prantl (5) point out that the adult floating leaves differ from the juvenile leaves by having long slender petioles and by being circinate in the bud. In shallow water, the young petioles grow from 8-10 cm. above the surface of the water, but sink back when mature. On the under side of the blades of the floating leaves are golden brown interstitial strands, which originate from the epidermis due to the intense golden brown color of the thick epidermal cells, and the neighboring colorless cells which do not have stomata.

Hildebrand (7), whose paper was the earliest accessible literature, states that he could not find any literature concerning the floating leaves of Marsilea and as a result he studied them. He found that adult petioles will not elongate when submerged but that the young petioles will grow above the water producing floating leaves. Some of the petioles grew to be three feet long which is an adaptation of the plant to the depth of the water. There are slightly sunken stomata on the upper and lower sides of the air leaves. On the upper side of the floating leaves there are twice as many stomata as on the upper side of the aerial leaves, but on the under side of the floating leaves the stomata are entirely lacking. The upper guard cells are, however, on a level with the epidermal cells.

Agnes Arber (1) makes the statement, based upon the findings of Karsten, that if tubes of oxygen-free air were inverted over the leaves of Marsilea, the growth of the petiole would continue after the lamina had come in contact with air. The conclusion is then drawn that the oxygen of the atmosphere checks further growth of the petiole.

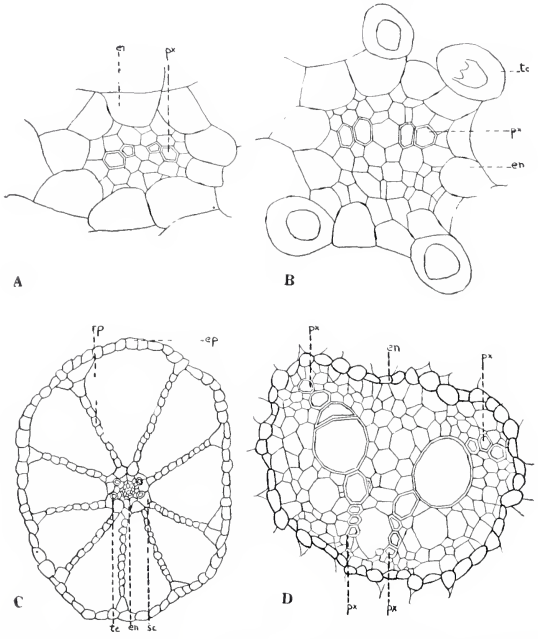


Fig. 2. *Marsilea quadrifolia.* A, cross section of the petiole of the first juvenile leaf, showing vascular strand; B, cross section of vascular strand of petiole of the third juvenile leaf; C, cross section of the petiole of fourth leaf; C, cross section of adult petiole, showing vascular bundle. *en*, endodermis; *tc*, tannin cell; *px*, protoxylem; *rp*, radiating partitions; *sc*, storage cortex; *ep*, epidermis.

Observations. Both the aerial and floating leaves have stomata on both surfaces but the stomata of the floating leaves are more abundant on the upper surface. The number of stomata on the upper surface of the floating leaves is greater than that on the upper surface of the aerial leaves. There are water stomata along the margin and when the plant is placed under a bell jar over night, small drops of water are found. It was seen that when the plants are grown in deep water, the young petioles did not grow above the surface of the water and then sink back as stated in Engler and Prantl. Brown interstitial strands are found on the under side of the older floating leaves.

Anatomy. Campbell (4) states that during the development of the first juvenile leaf, the cells are separated in places and form a series of longitudinal air chambers which are separated by radiating plates of tissue. The simple vascular strand traversing the axis is concentric and has a definite endodermis, but the tracheary tissue is very slightly developed.

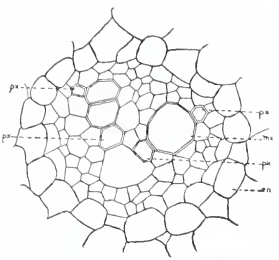


Fig. 3. *Marsilea quadrifolia.* Cross section of the vascular strand of the seventh juvenile leaf. *en*, endodermis; *px*, protoxylem; *mx*, metaxylem.

In regard to the structure, my observations are in accord with the account given by Campbell. In a cross section near the base of the first juvenile leaf, the vascular strand is in the center of the section and is surrounded by an endodermis and one layer of storage cells. Between this central strand and the epidermis, there is a series of six longitudinal air chambers which are separated by radiating plates of tissue one cell in thickness. These radiating plates or partitions extend from the storage cells to the epidermis where they may be one or more cells thick. The structure of the entire leaf is similar to that of the petiole of the fourth juvenile leaf which is shown in Fig. 2 C. At intervals in the older juvenile leaves, perforated diaphragm-like partitions, one cell in thickness, extend transversely across the intercellular chambers. This type of structure is common in the tissues of aquatic plants.

The vascular bundle is composed of two masses of protoxylem which are surrounded by the phloem. The cells of the endodermis are relatively large and show slight Casparian thickenings (Fig. 2, A). The xylem is composed of four annular or spiral tracheids. Tannin cells, which are characteristic of the other juvenile and adult leaves, were not found in the first leaf.

In all of the juvenile leaves, except the seventh, the vascular strand which is surrounded by a more evident endodermis, has two masses of protoxylem. They all have in the petioles a cortex which is made up of two regions, the storage tissue and the radiating partitions.

In a cross section of the petiole of the second juvenile leaf, there are 7-8 large intercellular spaces formed by radiating partitions. The storage cortex which is one cell thick, surrounds the endodermis. There are 2-3 tannin cells joining the endodermis and cortex. The vascular bundle is slightly larger than those of the cotyledon and the xylem is similar.

The cross section of the petioles of the third, fourth, and fifth leaf shows 7-8 intercellular spaces and 2-4 tannin cells. With each successive leaf, the vascular strand increases in size but the number of tracheids remains the same.

In the sixth juvenile leaf, there are 7-10 intercellular spaces and 4-5 tannin cells. The entire vascular bundle is larger than the preceding ones, and one of the xylem masses is composed of three tracheids.

In a cross section of the petiole of the seventh juvenile leaf, there are 9-10 intercellular chambers. One layer of cortical cells lies just beneath the epidermis. This is a characteristic of the adult leaves and stem. The bundle is composed of four masses of protoxylem which is a characteristic of the adult petioles. The entire bundle is composed of 7-8 tracheids (Fig. 3).

In the petiole of the adult leaf, there are 15 large air chambers formed by the radiating plates (Fig. 4, A).

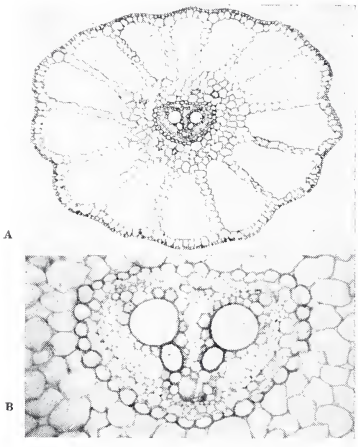


Fig. 4. *Marsilea quadrifolia.* Photomicrographs of cross sections of adult petiole. A, entire petiole; B, vascular bundle with surrounding cells more highly magnified.

The storage cortex is much thicker than in the juvenile leaves and it contains five or more tannin cells. The vascular bundle is composed of four masses of protoxylem which are surrounded by phloem (Figs. 2, D and 4, B).

A cross section of the leaf blade of the adult leaf shows that the palisade layer is not entirely compact but contains air spaces which are more abundant between the veins (Fig. 7, A). The spongy parenchyma is composed of rows of cells that extend from the palisade layer to the lower epidermis forming large intercellular spaces. The upper epidermis has thicker cell walls than those of the lower epidermis. Each vein which is surrounded by border parenchyma is composed of 3-6 tracheids. Just outside of the border parenchyma are 3-6 tannin cells.

Stem. Luerssen (8) states that in Marsilea the stems are frequently creeping for a long distance and are supplied with numerous branched roots which develop near the vegetative tip. In comparison with the size of the plants, the stems are thin, cylindrical, more or less well branched and the branches are extra axillary, developing on the sides below the leaves. The growing point is not enveloped by young leaves but is densely hairy, while the older parts are frequently bare. The central vascular cylinder, closed siphonostele, shows a narrow gap, only beneath the insertion of the leaves above the branching where the vascular strand enters the leaf petiole, through which the pith and cortex are united. The cortex is perforated by air chambers which are longitudinally placed, separated by radial plates of one layer of cells.

Campbell (4) makes the statement that the solid vascular cylinder of the young stem is later usually replaced by a tubular one. Its structure is concentric with phloem completely surrounding the xylem, and it has both an inner and an outer endodermis. When the plants are completely submerged, the ground tissue is mainly parenchyma, but in the terrestrial forms, sclerenchyma may be developed in the cortex of the stem and petiole.

Bower (3) points out that in Marsilea, the stem is traversed by a solenostele with inner phloem and endodermis. The undivided leaf trace separates a sector of the ring. The cortex is differentiated into an inner storage tissue, separated by a thin sclerotic band from an outer tissue containing large radiating lacunae with thin parenchyma septa. This is a peculiarity seen in aquatic plants. The vascular supply to the stalk of the sporocarp comes off by marginal abstriction. The petiolar trace is marked off by the endodermis from the parenchyma which is differentiated into storage tissue having tannin sacs, and an outer porous sys-

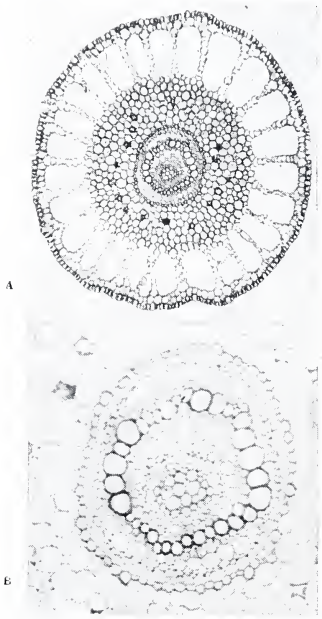


Fig. 5. *Marsilea quadrifolia*. A, photomicrograph of young rhizome; B, enlargement of the siphonostele. *oen*, outer endodermis; *ien*, inner endodermis; *p*, pith.

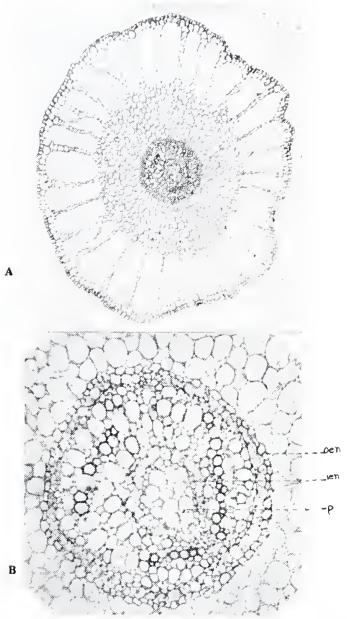


Fig. 6. *Marsilea quadrifolia*. A, cross section of the adult rhizome; B, stele enlarged showing vascular tissue.

tem with peripheral epidermis and sclerotic tissue between. The roots are diarch with a conical apical cell, and a regular lacunar cortex.

De Bary (2) states that the sieve tubes are fitted one on another with pointed or horizontal ends and have sieve plates on the latter and also on the surface which touches other sieve plates. The pores are very numerous.

According to Sinnott (11) there are three main types of leaf traces in the ferns which may be characterized as monarch, diarch, and triarch, possessing one, two, or three masses of protoxylem respectively. The first type is found in Osmundaceae and Ophiglossaceae, the second in Maratticeae, and the third in all other families of the Filicales. He states that in Marsilea the leaf trace as it goes from the stele, is an arc with three endarch protoxylem. The median one soon forks dividing the trace into two bundles each of which has a mass of protoxylem at either end.

In another paper (10) Sinnott states that in certain ferns, the leaf trace is small as it leaves the stele and increases in size as it goes through the base of the petiole. In those types of ferns where the rhizome is superficial and the petiole arises directly from it, there is no difference in either the petiole or the vascular bundle.

Observations. In a cross section of the young stem there are about 30 intercellular spaces due to rows of radiating partitions (Fig. 5). The storage cortex is about 10 cells thick. There are 5-7 masses of proto-

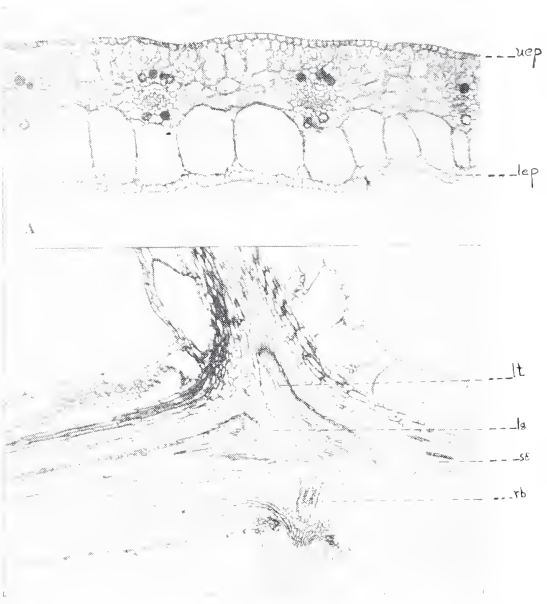


Fig. 7. *Marsilea quadrifolia.* A, cross section of the adult leaf blade. *ucp,* upper epidermis; *lep,* lower epidermis. B, longitudinal section of stem, showing the origin of petiole and root; *lg,* leaf gap; *rb,* root branch; *lt,* leaf trace; *sc,* storage cortex.

xylem in the young stem. As the stem matures these masses of protoxylem are connected by metaxylem to form a circle. This is surrounded on the inside and outside by phloem and an endodermis. The cells of the endodermis and pith have thickened walls (Fig. 6, A and B).

A suitable cross section was made which showed the connection between the siphonostele and leaf and root. Here it is observed that the petiole has four masses of protoxylem which are separated at the median arc by one large parenchyma cell (Fig. 2, D). The vascular strand of the petiole is of the same size while in the cortex of the stem as it is after leaving the cortex.

The manner in which the leaf trace leaves the stele is shown in Fig. 7. The pith and cortex are united by means of the gap. The root arises from the base of the petiole. Roots and petioles originate at the same node but there may be roots produced without the petioles. Branches are also produced at the nodes but there are no gaps formed. The xylem of the root is diarch.

There may be several variations in the number of blades produced on different plants. The fourth, fifth, sixth, and seventh juvenile leaves of one plant had two blades and the eighth which was the adult had four blades. In another instance an adult leaf had five blades instead of four. The fifth blade was similar in size and shape to those of the second juvenile leaf. The adult leaf may also consist of three blades as is found in plants grown in air. It was also found that the sixth leaf may be cleft instead of two lobed.

Plants were grown in air on soil that was continually moist. The growth was slower than that in the earthen-ware vessel, and the entire plant was smaller. More stomata were produced on the upper and lower surfaces of these leaves than on those grown under water. In the older juvenile leaves, the stomata on the upper surface had chloroplasts in the guard cells while those on the under side were colorless. The adult leaf was about 30-40 mm. in length (Table 2).

Neither the plants grown in the air nor in the earthen vessel produced a long creeping stem. The stem remained very short as it did while the juvenile leaves were produced. Hildebrand (7) calls attention to the fact that during the growing period of one season, the stem attained a length of ten feet.

Plants were grown in water 14 inches deep and all of the adult leaves were floating, but the length of the petiole was greater than the depth of the water. In one case a petiole attained a length of 19 inches.

SUMMARY

1. *Marsilea quadrifolia* has seven juvenile leaves. The first five have one blade and the next two have two blades.

2. The juvenile and adult floating leaves have stomata more abundantly on the upper surface while the aerial adult leaves have the same number of stomata on both surfaces. Both the juvenile and adult leaves have water stomata along the margin near the closed veins.

3. The petioles of the first six juvenile leaves have two masses of protoxylem and the seventh juvenile leaf has four masses which is a characteristic of the adult petiole. The seventh juvenile leaf is circinate in the bud which is a character also found in the adult leaf.

4. The vascular system of the rhizome is an amphiphloic siphonostele. A gap is present on the adaxial side where the leaf trace leaves the stem. The root arises from the base of the petiole.

5. The stem and petioles of the adult and juvenile leaves are composed of storage and radial cortex. In all leaves except the first, tannin vessels are found in the cortex.

The writer wishes to express her appreciation to Dr. David M. Mottier for his valuable suggestions and kindly encouragement during the progress of this investigation and her indebtedness to Dr. Paul Weatherwax for taking the photomicrographs used in the paper.

TABLE 1. Juvenile Leaves

	Number of veins	Number of tannin vessels	Number of air spaces	Number of xylem vessels
1st leaf	1	none	6	3-4
2nd leaf	5-6	2-3	7-8	3-4
3rd leaf	7-10	2-4	7-8	3-4
4th leaf	10-12	3-4	7-8	3-4
5th leaf	13-17	3-4	7-8	4-5
6th leaf	13-14	4-5	7-10	4-5
7th leaf	21-24	4-5	7-10	7-8

TABLE 2. Difference in Size due to Environment
(Measurements in mm.)

Where Grown	Size of Cotyledon	Second leaf	Third leaf	Fourth leaf	Fifth leaf	Sixth leaf	Seventh leaf	1st adult leaf	2nd adult leaf	3rd adult leaf
Glass Jar:										
14 days.....	11 long 1 wide	6 1.5	9 2.5	11 3.5	9 4					
23 days.....	11 long 1 wide	8 2	10 3	11.5 3	12 4.5	16 3.5 2 blades	19 4.5 2 blades	41 1 blades not unfolded		
27 days.....	11 long 1 wide	7 1.5	10 2.5	11 3	14 4	18 3.5 2 blades	22 4 2 blades	9cm 4 4 blades		
33 days.....	10 long 1 wide	7 1.5	9 2.5	11 3	14 5	16 7 partly lobed	22 5 2 blades	10.5cm 9 2 blades	11.3cm 7 4 blades	14cm 12 4 blades
							Rhizome	1	2	3
Grown in Crock:										
14 days.....	9 long 1 wide	8 1.5	9 2.5	6 2						
23 days.....	10 long 1 wide	8 1.5	9 2	9.5 3	10 3.5	18 2 2 blades				
27 days.....	11 long 1 wide	8.5 1.5	9 2.5	10 3.5	14 4	40 3 2 blades	3.5 1			
33 days.....	10 long 1 wide	8.5 1.5	9 2.5	10.5 3	12 4	53 3.5 2 blades	63 5.5 2 blades	57 3 4 blades		

Table 2. Continued

Grown in Air:										
15 days.....	8 long .75 wide	6 1	7 1.5	2 .75						
22 days.....	7 long .75 wide	6 1.5	7 2	7.5 3	13 4					
28 days.....	7 long .75 wide	5 1.5	6 2	9 3.5	14 5	16 4 2 blades	7 1			
37 days.....	7 long .75 wide	6 1	8 1.5	9 2	15 5	18 3 2 blades	30 6 2 blades	42 4 4 blades		

BIBLIOGRAPHY

1. Arber, Agnes. Water plants. Camb. Univ. Press, 284. **1920.**

2. De Bary, A. A comparative anatomy of the phanerogams and ferns. Oxford. **1884.**

3. Bower, F. O. The ferns. Camb. Univ. Press, **2**:176-192. 1926.

4. Campbell, D. H. Mosses and ferns. 3rd Ed., 417. **1918.**

5. Engler, A. and Prantl, K. Die Naturlichen Pflanzenfamilien **1** (4):403-421. 1902.

6. Gwynne-Vaughan, D. T. Observations on the anatomy of solenostelic ferns. Ann. Bot., **15**:71-98. 1901.

7. Hildebrand, F. Ueber die Schwimmblätter vor Marsilia und einigen anderen amphibischen Pflanzen. Bot. Zeit., **28**:1-8. 1870.

8. Johnson, D. S. On the development of the leaf and sporocarp in *Marsilia quadrifolia*: Ann. Bot., **12**:119-146. 1898.

9. Karsten, G. Ueber die Entwickelung der Schwimmblätter bei einigen Wasserpflanzen. Bot. Zeit. Jahrg., **46**:565-578. 1888.

10. Sinnott, E. W. Factors determining the size of the vascular system in fern petioles. Absts. Papers Read Gen. Sect., Bot. Soc. Am. **1931.**

11. Sinnott, E. W. The evolution of the filicinean leaf trace. Ann. Bot., **24**:167-191. 1911.

POLLEN STATISTICS FOR TWO INDIANA BOGS

PAUL KING HOUDEK, High School, Robinson, Illinois

INTRODUCTION

This is a report of findings from two bogs which reports are parts of a series of similar investigations by the author throughout Indiana and Michigan. The work is under the supervision of Professor G. D. Fuller of the department of botany of the University of Chicago.

LOCATION AND DESCRIPTION OF THE BOGS

The two bogs are both in northern Indiana and at approximately the same latitude. They are one hundred twenty miles apart. Both were drilled during the summer of 1932.

The Center Lake bog is located around the northwest end of Center Lake, one mile northwest of Angola, Steuben County, Indiana. The lake and bog are located in a glacial depression and are quite typical of the region. The peat deposit was described by A. E. Taylor (5). No detailed study was made of the present day flora of the bog, but the bog plants of the following genera were noted: Sphagnum, Carex, Typha, Chamaedaphne, Rhus, and Larix.

The Mineral Springs bog is located in the sand dunes of northwestern Indiana fifteen miles east of Gary and half a mile north of United States Highway No. 12. This bog developed in a depression between sand dunes of the post-Toleston age and is quite similar to other dune bogs. Taylor (5) describes the bogs of this region. The surface flora is similar to that at Center Lake except that, due to a recent ditching, considerably less Sphagnum was found.

METHODS

Collection. Samples of the deposited materials were collected by means of a Hiller Peat Borer. Two samples for microscopic examination were very carefully removed from the center of each core and placed in clean glass tubes. Larger samples for macroscopic examination were taken from each core and placed in soil boxes.

Preparation. The peat was prepared for microscopic examination following the method described by Voss (6) in which potassium hydroxide is used to loosen the fragments composing the peat. Potzger, J. E., in a paper presented before this section of the Academy in 1931, objected to the use of potassium hydroxide on peat on the basis that it would distort the pollen grains. No demonstrations or other evidence of the amount or character of the distortion was presented. It is reasonable to expect some distortion, but until a better method of loosening the pollen grains from the other material in the peat has been discovered, the method used seems to be the most advisable. To avoid contamination,

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

all of the materials were handled throughout the process of preparation with care approaching that used in bacterial culture work.

Examination and Identification. The pollen grains were identified by comparing them with a comprehensive collection of modern pollens. Sears' (3) work on pollen was helpful in identification. At least one hundred fifty pollen grains were identified and tabulated for each sample. Peat types were determined by comparison with type samples.

RESULTS

The results of the investigations are presented in the pollen diagrams and tabulated pollen percentages.

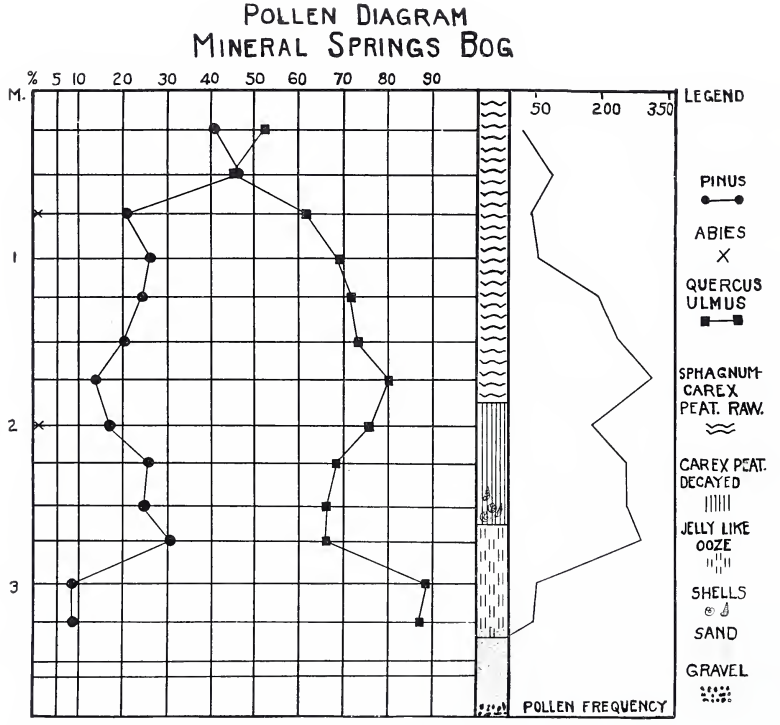


Fig. 1. Pollen diagram Mineral Springs bog.

Obviously only the more significant types of pollens could be represented on the pollen diagrams. Salix, Larix, Corylus, and Alnus are so general in their distribution that their pollen grains were omitted from the calculations as insignificant. Pollen frequency is the calculated number of pollen grains to be found on one square centimeter of the slide of that sample.

SIGNIFICANCE

Pollen Percentages. If the statement made by Auer (1), "The pollen content of the successive layers of the individual peat bogs is a

TABLE 1. Percentages of the Significant Tree Pollens Mineral Springs Bog

Depth M.	Abies	Pinus	Tsuga	Betula	Carpinus	Ostrya	Fagus	Fraxinus	Juglans	Liquidambar	Quercus	Ulmus	Quercus and Ulmus
.22	.....	40.7	1.2	.6	.....	.....	2.5	.....	1.9	.....	50.3	2.5	52.8
.50	.....	46.5	.6	3.3	.6	.....	1.9	.....	1.3	.....	42.5	3.3	45.8
.72	.6	20.8	2.6	3.2	.....	.....	.....	.....	.6	.6	58.4	3.2	61.6
1.00	.....	26.0	1.9	.6	.....	.....	1.3	.6	.....	.....	65.5	3.9	69.4
1.22	.....	24.7	.....	1.9	.....	.....	.6	.....	1.2	.....	67.9	3.8	71.7
1.50	.....	20.5	.....	1.9	.....	.....	2.5	.6	.....	.6	64.0	9.0	73.0
1.72	.....	14.0	.....	2.6	.....	.....	1.3	.6	.6	.....	78.8	1.3	80.1
2.00	.6	17.2	.....	.....	.....	.....	5.2	1.2	.....	.....	65.5	10.2	75.7
2.22	.....	25.5	.6	1.8	.6	.....	3.6	1.2	.....	.....	67.5	1.2	68.7
2.50	.....	24.5	.....	4.2	.....	.....	3.6	.6	.6	.6	63.5	2.4	65.9
2.72	.....	30.1	.....	1.2	.....	.....	1.9	.....	.....	.6	64.6	1.2	65.8
3.00	.....	8.0	.....	.6	.....	.6	1.3	.....	.6	.....	84.5	4.0	88.5
3.22	.....	8.5	.....	.6	.....	.....	2.6	.....	1.3	.....	81.0	5.9	86.9

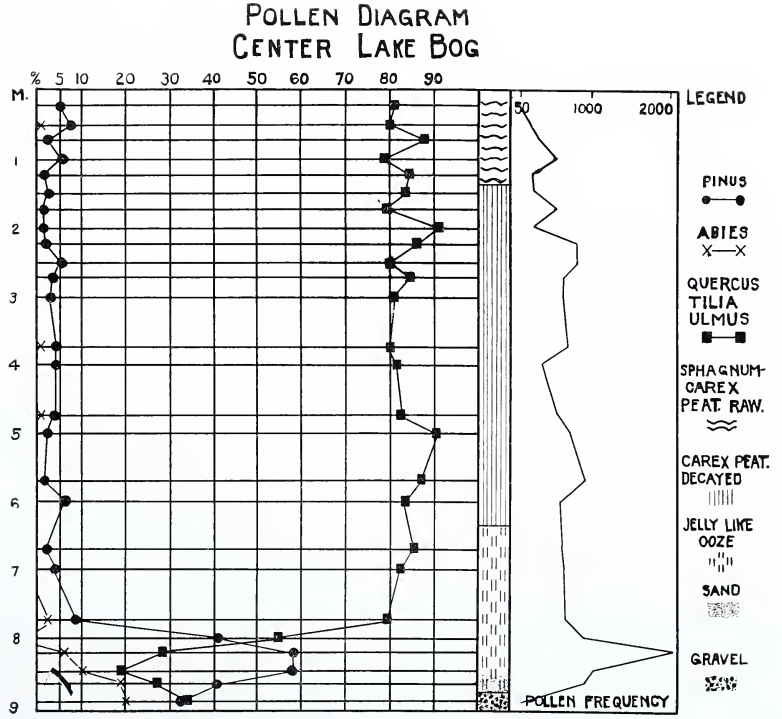


Fig. 2. Pollen diagram Center Lake bog.

TABLE 2. Percentages of the Significant Tree Pollens Center Lake Bog

Depth M.	Abies	Picea	Pinus	Tsuga	Betula	Carpinus	Ostrya	Fagus	Fraxinus	Juglans	Liquidambar	Quercus	Tilia	Ulmus	Quercus, Tilia and Ulmus
.22	....	....	5.1	1.2	2.5	....	1.2	3.8	....	4.5	....	68.0	.....	13.0	81.0
.50	.6	....	7.4	....	4.0	.6	.6	5.2	1.1	.6	....	73.9	.....	6.6	80.5
.72	....	....	2.6	....	1.3	....	.6	4.6	.6	2.0	....	80.0	1.3	6.6	87.9
1.00	....	....	5.7	.6	3.8	.6	.6	5.2	3.2	1.2	....	71.2	.....	7.6	78.9
1.22	....	.6	1.3	....	3.9	....	....	6.5	1.3	1.9	....	78.0	1.9	4.6	84.5
1.50	....	....	2.5	....	3.2	.6	1.2	3.8	1.2	2.5	.6	78.0	.6	5.2	83.8
1.72	....	....	1.3	....	3.9	1.3	.6	7.8	2.6	1.9	.6	72.4	.....	7.2	79.6
2.00	....	....	1.2	.6	1.8	.6	....	3.6	.6	.6	....	80.0	.....	11.1	91.1
2.22	....	....	1.8	....	1.2	.6	.6	8.7	.6	.6	....	77.8	.....	8.1	85.9
2.50	....	....	5.3	....	1.2	....	....	12.0	1.2	....	....	76.0	.....	4.1	80.1
2.72	....	....	3.4	....	1.7	....	2.6	4.6	.6	1.1	.6	77.2	1.1	6.3	84.6
3.00	....	....	3.1	.6	3.7	....	....	10.6	.6	....	....	76.0	.....	4.9	80.9
3.72	.5	.5	4.7	.5	.5	....	....	8.0	4.2	.5	....	75.0	.....	5.3	80.3
4.00	....	....	4.6	.6	2.6	....	2.6	5.3	2.0	.6	....	70.0	.6	10.8	81.4
4.72	.6	....	4.0	....	1.1	....	....	8.6	1.7	.6	....	72.0	.6	9.7	82.3
5.00	....	....	2.7	.5	.5	....	....	1.6	2.1	1.6	....	77.0	.5	13.0	90.5
5.72	....	....	1.7	....	2.3	....	.6	5.2	1.2	1.2	....	76.0	.6	10.4	87.0
6.00	....	....	6.1	....	1.2	....	.6	6.7	.6	1.2	.6	69.0	.....	14.6	83.6
6.72	....	....	2.2	....	3.3	....	1.7	6.7	.6	....	....	66.5	.6	19.5	85.6
7.00	....	....	4.1	....	5.1	....	.6	4.1	1.7	1.2	....	71.0	.....	11.4	82.4
7.72	2.7	....	9.1	....	4.8	....	....	3.2	....	.5	....	65.0	1.6	12.8	79.4
8.00	....	....	40.5	....	1.7	....	....	2.7	....	....	....	41.0	1.5	12.6	55.1
8.22	5.8	....	59.0	....	6.4	....	....	....	.6	.6	....	18.0	.....	9.9	27.9
8.50	10.2	4.2	58.6	.6	3.6	....	1.2	1.2	.6	....	....	14.6	.6	4.2	19.4
8.67	19.0	6.7	40.5	....	6.1	....	....	.6	....	....	....	21.5	.....	5.6	27.1
8.95	20.5	5.3	32.5	....	5.9	....	....	1.3	....	.6	....	29.9	.....	3.9	33.8

direct indication of the comparative abundance of the different kinds of trees growing as the peat layers formed," is true, this investigation shows changes in the tree flora of the regions in which the bogs are located. The bottom deposits of the Mineral Springs bog contain a predominance of Quercus-Ulmus pollens. The later deposits show a marked increase in the Pinus pollens. In the Center Lake bog, the older deposits contain a high percentage of Abies pollen with the Pinus pollens practically equivalent to the Quercus-Tilia-Ulmus group. This situation gives way to a Pinus predominance which is followed by the Quercus-Tilia-Ulmus predominance which continues to the surface. The greater antiquity of the Center Lake bog is evident from the high percentage of Abies pollen in the bottom layers. This is typical for the majority of bogs in Wisconsin, Illinois, Michigan, southern Canada, and Ohio that have been investigated by Auer (1), Sears (4), Voss (6), and the author (2). The predominance of Quercus-Ulmus in the oldest layer of the Mineral Springs bog would indicate that deposition of material began there considerably later than in the Center Lake bog. This would be expected from the situation of the Mineral Springs bog within the Tolesston beach lines of Lake Chicago. The Center Lake bog is entirely outside the beach lines of Lake Chicago and hence in a much older area.

These studies may lead to a comparative statement as to the age of the sand dunes. The marked difference in the later deposits of the two bogs would seem to indicate that the immediate vicinity has considerable influence on the percentages of pollens in the deposited materials.

The primary conclusions drawn from most of the investigations in this field have been concerning climate changes inferred from changes in the flora indicated by the pollen grains found at the different levels. Doubtless most of these conclusions have been well founded. It is the belief of the author that broad interpretations of climate changes should be reserved for papers of greater scope than the present one.

Peat Types. The peat types indicate the character of the surface at the time of deposition. The material on the bottom was doubtless washed in from the surrounding terrain. The ooze represents deposition in the open deep water. The peats represent deposition in shallow water or from the underside of floating vegetation mats. The absence of sand layers in the Mineral Springs bog indicates that there have been no major dune movements near the bog since its inception. In this respect it differs from a Michigan dune bog investigated by the author (2).

Pollen Frequency. If a uniform procedure is followed in preparing the slides, the calculated pollen frequency will indicate the relative abundance of pollen at the various levels. The highest frequency in each bog is found in the deep-water deposited material. The full significance of pollen frequency and its relationship to pollen percentages and peat types has not yet been determined.

SUMMARY

1. The two bogs investigated exhibit striking differences.

2. The deposition of material in the dune bog probably began considerably later than that in the bog in the glacial depression.

3. The Center Lake bog indicates a forest succession in that region of first, Abies-Pinus and Quercus; second, Pinus; third, Quercus-Tilia-Ulmus.

REFERENCES

1. Auer, Vaino. Peat Bogs in Southeastern Canada, Canada Department of Mines, Memoir 162. **1930.**

2. Houdek, P. K. Preliminary Pollen Statistics for Two Michigan Bogs. Trans. Ill. State Acad. Sci. **25.** 1932.

3. Sears, P. B. Common Fossil Pollen of the Erie Basin, Bot. Gaz. **89**:95-106. 1930.

4. ———. A Record of Post-Glacial Climate in Northern Ohio. Ohio Journ. Sci. **30** (4):205-217. 1930.

5. Taylor, A. E. On the Peat Deposits of Northern Indiana, **31st** Annual Report, Indiana Department of Geology and Natural Resources 1906.

6. Voss, John. Preliminary Report on the Paleo-Ecology of a Wisconsin and an Illinois Bog. Trans. Ill. State Acad. Sci. **24** (2):130-137. 1931.

SOME ALGAE OF VIGO, GREENE AND DAVIESS COUNTIES

LOUISE M. LOVE and ROBERT L. ROGERS, Indiana State Teachers College

The algae of Indiana have been studied by several workers during the past quarter-century, and the plants reported from this state represent nearly every genus of the Cyanophyceae and Chlorophyceae. The algae of Vigo County were probably never carefully studied until Smith (5) did his work. Although much of his material is from Vigo County, he collected and studied specimens from many regions of the state. The plants reported in this study were for the most part collected from Vigo County. Some material was obtained from Greene County and Daviess County. Material was collected and preserved during the period from December 15, 1931, until June 10, 1932.

The findings of this study were checked against previous records of Andrews (1) (2), Palmer (3) (4), Smith (5), and White (6).

Thirteen plants including one genus, nine species, and three varieties or forms not previously reported for the state are recorded in this study. All of these were from Vigo County except *Zygnema pectinatum* var. *conspicuum*. Twenty-one plants not previously reported for Vigo County are recorded in addition to the ones not previously reported for the state. The algae found are listed along with a key to the symbols used.

ALGAE SYSTEMATICALLY ARRANGED

Class I. Myxophyceae

[1]*Merismopedia tenuissima* Lemmermann. May 16, 1932.

Class IV. Heterokontae

[3]*Ophiocytium cochleare* (Eichwald) A. Braum. Feb. 20, 1932.
[4]*Tribonema bombycinum* f. *minor* Wille. May 2, 1932.

Class V. Chlorophyceae

[1]*Gloeocystis vesiculosa* Naeg. June 8, 1932.
Sphaerocystis schroeteri Chod. Feb. 20, 1932. Reproducing—zoospores of two sizes present.
[3]*Pediastrum tetras* (Ehr.) Ralfs. Mar. 19, 1932.
[1]*Characium sublatum* A. Braum. Jan. 25, 1932.
[3]*Actinastrum gracillimum* Smith. May 16, 1932.

[1] Species—not previously reported from state.
[2] Variety of form—not previously reported from state.
[3] Species—not previously reported from Vigo County.
[4] Variety—not previously reported from Vigo County.
[5] Genus—not previously reported from state.
[6] Collected from other counties than Vigo.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

[3]*Ankistrodesmus falcutus* (Corda) Ralfs. June 1, 1932.

[3]*Scenedesmus bijuga* (Turpin) Lagerheim. May 2, 1932.

[6]*Scenedesmus bijuga* var. *alternans* (Reinsch) Borge. May 31, 1932. Daviess Co.

[3]*Scenedesmus denticulatus* Lagerheim. May 25, 1932.

[6]*Scenedesmus longus* Meyen. May 31, 1932. Daviess Co.

[3]*Ulothrix tenerrima* Kuetzing. Mar. 26, 1932.

[1]*Stigeoclonium stagnatile* (Hazen.). Mar. 26, 1932.

[3]*Aphanochaete repens* A. Braum. Feb. 20, 1932.

[5]*Chaetosphaeridium globosum* var. *depressum.* W. and G. S. West. Feb. 26, 1932.

[5]*Chaetosphaeridium pringsheimii* Klebahn. Mar. 9, 1932.

Oedogonium borisianum var. *westii.* Tiffany and Brown. April 3, 1932. Larger than recorded measurements. Oogonium: 64-68.2 Dia.; 86.4-99.2 Leng.; Ospore; 64-68.2 Dia.; 77.8-81. Leng.; Veg. Vell: 32.-35.2 Dia.; 81.-140. Leng.; Suffultory Cell: top 48. Dia.; bottom 44. Dia.; Pore: Superior; Dwarf-males present.

[3]*Oedogonium boscii* (Le Clerc) Wittrock. Feb. 18, 1932.

[4]*Oedogonium boscii* var. *occidentale* Hirn. Feb. 18, 1932.

[4]*Oedogonium capilliforme* var. *diversum* (Hirn) Tiffany. May 15, 1932.

[3]*Oedogonium cardiacum* (Hass.) Wittrock. April 24, 1932.

[3]*Oedogonium crassum* (Hass.) Wittrock. April 24, 1932.

[1]*Oedogonium decipiens* var. *africanum* Tiffany. April 5, 1932.

[1]*Oedogonium flavescens* (Hassell) Wittrock. April 3, 1932.

[3]*Oedogonium fragile* Wittrock. April 27, 1932.

[1]*Oedogonium pachyandrium* Wittrock. April 18, 1932.

[3]*Oedogonium paludosum* (Hassell) Wittrock. April 17, 1932.

[3]*Oedogonium rufescens* Wittrock. April 12, 1932.

[1]*Oedogonium sodiroanum* Lagerheim. April 19, 1932.

[3]*Oedogonium suecicum* var. *australe* (G. S. West) B. H. Smith. April 3, 1932.

[1]*Spirogyra areolata* Lagerheim. April 19, 1932.

[2 6]*Zygnema pectinatum* var. *conspicuum* (Hass.) Kirchner. Mar. 24, 1932. Greene Co.

[4]*Cosmarium granatum* var. *subgranatum* Nordst. April 17, 1932.

[2]*Cosmarium margaritatum* f. *minor* Boldt. June 1, 1932.

[3]*Staurastrum furcigerum* De Brebisson. Feb. 20, 1932.

[3]*Phacus longicaudus* (Ehrenb.) Duj. Mar. 2, 1932.

BIBLIOGRAPHY

1. Andrews, F. M. 1926. A List of Algae of Monroe County, Indiana, II. Proc. Ind. Acad. Sci. 36:223-225.

2. ———— 1929. Algae of Monroe County, Indiana, III. Proc. Ind. Acad. Sci. 39:57-58.

3. Palmer, C. Mervin 1929. Algae of Indiana—a classified check list of those published between 1875 and 1928. Proc. Ind. Acad. Sci. 38:109-121.

4. ———— 1932. Plankton Algae of White River in Marion County and Morgan County, Indiana. Butler University Botanical Studies 2:125-131. No. 10.

5. Smith, B. H. 1931. The Algae of Indiana. Proc. Ind. Acad. Sci. 41:177-206.

6. White, Helen L. 1930. The Phytoplankton of a Solution Pond with Special Reference to the Periodicity of Certain Algae. Proc. Ind. Acad Sci. 40:123-138.

6—48585

THE TYPES OF LINNAEAN GENERA

J. A. Nieuwland, Notre Dame

There seems to be a rather general belief among botanists (and zoologists too) that Linnaeus nowhere did anything to indicate the type species of his genera. In fact, on occasion, I have heard botanists give expression to the statement that the concept of a Linnaean genus was not meant by him to be limited in any way by types as now understood, but that the word genus as he viewed it, included equally all species included under the name without any emphasis whatever to be put on the concept to single out a single species as a type species of that genus in the modern view. Whatever may or may not have been the Linnaean ideas, nothing is more certain however, than the fact that Linnaeus not only expected that future botanists with possibly different ideas of the term genus, might, and probably would, divide his groups differently than he had done. He even went so far as to formulate rules for this *process* of segregation, not arbitrarily made as do the botanical congresses of today, but based on sound reason and good judgment. I go so far as to assert that were the Linnaean standards observed, we should not need botanical congresses at all. These latter are too often swayed by motives of feasibility and fail to meet a problem face to face on a logical basis.

For the reason that such remarkable works as the "Critica Botanica" and the "Philosophia Botanica" contain no publication of new genera and species, botanists generally know nothing about them, or if they do, prefer to ignore them. In these works the great 18th century taxonomist gives all the reasons for his methods and at the same time explains the principles and laws of nomenclature and taxonomy, and that too, in a more comprehensive and logical way than the makeshift methods of our modern scientific nomenclatorial congresses.

Let me, at the outset, state that inasmuch as we live in an age of democracy, or I think it were better to say an age of voting, there seems to have arisen the idea that truth can be settled by ballot taxonomically, or, for that matter, politically. Of course, it is obvious that there is nothing more dogmatic than a truth or a principle, and yet, throwing facts and principles aside, congresses, since they have started, have tried to agree on things by the force and number of ballots although it is absolutely useless to do so unless the matter voted on is true, logical, a fact, or a principle. Moreover, if anything is a truth, a principle, a fact, and logically reasoned out, then no number of votes or ballots can make it untruth, illogical, or a guess. How often has a man with a truth stood against the world of ballots and opinions and won? I have said and repeated times without number that nomenclatorial problems will never be solved by legislation and votes. Logic

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

and reason alone will prevail in the long run, and the more nomenclatorial congresses we have, the more involved become the difficulties, the further off seems the solution of them.

Linnaeus, the opinion of many modern taxonomists to the contrary notwithstanding, left rules for the segregation of his own genera, and by implication, also indicated what we may call a way of determining his types.

On page 197 of his "Philosophia Botanica" (1751) (or page 197 of the second edition of 1755 of the same work), he says:

"246. Si Genus receptum, secundum jus naturae (162) et artis (164), in plura dirimi debet, tum nomen antea commune manebit vulgatissimae et officinali plantae.

CORNI genus supponatur dividi in tria:

A. Arbor floribus involucratis umbellatis.
B. Herba floribus involucratis umbellatis.
C. Arbor floribus non involucratis cymosis.
Sic dicenda A. *Cornus*, B. *Mesomora*, C. *Ossea*, nec licet A dici *Mesomoram* aut *Osseam*."

Linnaeus' genus A is therefore clearly to be retained as *Cornus*, that is, as typified by *Cornus mas* which, by the way, was regarded as the typical *Cornus* since the time of Pliny and by all the writers to the time of Linnaeus, or most of those after, for that matter.

Mesomora Rudbeck has *C. canadensis* as type and has another species *C. Suecica*.

Ossea Rudbeck, contains the cymose flowering dogwoods containing the group with largest number of species, now called *Svida*, having most of our American shrubs. The type is *C. sanguinea* L.

In Rhodora, volume 34, page 29 (1932), Mr. Oliver Farwell discusses certain generic segregates or supposed generic segregates of Rafinesque[1].

As briefly as I can state the situation, Farwell says that certain segregated genera of Rafinesque have no valid standing. There seems, perhaps, a chance that the context and type of print, order, etc., might lend force to quite a different conclusion, Farwell to the contrary notwithstanding. Had Farwell made a photostatic print in Rhodora of the original of pages 58 and 59 of that work, perhaps the matter might look otherwise especially to such readers as are habituated by long study to Rafinesque's rather suggestive ways of proposing new genera. This may, however, well be a matter of opinion, and I am not here concerned with the question whether anyone may or may not consider Rafinesque's "groups" genera. Moreover, the name *Mesomora*, for example, has been badly misinterpreted by Rafinesque and he himself has made some rather unfortunate mistakes in grouping the species in the reference quoted by Farwell.

On page 30, Rhodora, Farwell, referring to Rafinesque, makes the following interesting statement:

"Under the international rules, the name Eukrania must be re-

[1] Rafinesque. Alnographia Americana, pp. 58-66 (1838).

tained for the group having the largest number of species, hence I choose *Cornus canadensis Linn.* as its type."

To select arbitrarily a type of a Linnaean genus, where that author has already done so, leads to taxonomic anarchy. Rafinesque combines the bracted cornels, namely the tree *Cornus mas* (*C. mascula Raf.*) with the two herbaceous cornels *C. canadensis* and *C. succica.* These three are the only species in A "group". If Farwell is selecting *C. canadensis* as the type of the Linnaean aggregate genus *Cornus,* he is presumptive, because Linnaeus himself picked *his own type C. mas.* as I shall show presently. If Farwell means, in spite of his own statements to the contrary, that he selects *C. canadensis* as the type of the group Eukrania containing *C. canadensis, C. mas* and *C. suecica,* it still will not do, because *Eukrania* does not have precedence over *Chamaepericlymenum,* the latter having been proposed by Hill in 1756. I called attention to this as early as 1909, and Farwell might have found this in his own library with only a few minutes search, although the Kew Index, as sometimes happens, did not take cognizance of the report.

We may sum up the question in the following manner. Linnaeus had five species in the 1st edition of the Species Plantarum of 1753.

C. mas, is the Cornus of Pliny, Columbella, Vergil, and the other authors before him, and therefore the type of his genus. *C. sanguinea* is the type of *Ossea* Rivinus (or, as we call it now, *Svida*). *C. canadensis* and *C. seucica* are in *Mesomora* now called *Chamaepericlymenum.* J. Hill (1756) British Herba, p. 331. *C. florida L.* had not been segregated before Linnaeus, but was associated with *C. mas.* We here append Linnaeus' further discussion in the "Philosophia Botanica": "Sic dicenda A. *Cornus* B. *Mesomora* C. *Ossea.* nec licet A dici Mesomoram aut Osseam."

Linnaeus' genus A. is therefore clearly to be retained as *Cornus,* that is, as typified by *Cornus mas* which, by the way, was regarded as the typical cornus since the time of Pliny and by all the writers to the time of Linnaeus, or after, for that matter.

Mesomora Rudbeck has *C. canadensis* as type, and has another species, *C. suecica. Ossea* Rudbeck contains the symose flowering dogwoods, containing the group with largest number of species. Even more convincing and explicit is the rule that Linnaeus proposed in the "Critica Botanica". I quote the passage in full because of its importance to the matter under discussion. The meaning is obvious.

"246. Si genus receptum Secundum jus naturae et artis, in plura dirimi debet, tum nomen antea commune manebit vulgatissimae et officinali plantae.

Varia nomina plantis imposuere veteres, rarius observantes genera. Systematici nullo habito respectu ad veterum divisiones, quae fructificatione convenerunt, ad idem genus idemque nomen commune reduxerunt; reliqua omnia nomina ejecerunt. Cum haec reductio, secundum assumta principia systematica artificialia, saepe erronea evaserit, diviserunt iterum haec genera recentissimi Systematici secundum principia naturalia in plura, tumque revocata fuere prius expulsa nomina: quae, si aliis, quam olim, nunc connectierentur plantis, inextricabilis inde oriretur confusio. Exemplis res clarior evadet.

Cornus, Ossea, Mesomora genere conjungi debent, adeoque excludi duo nomina, tertium persistere: non licet ex hisce tribus, si per se bona sint nomina omnia, quodcunque horum placeat, indifferente assumere; sed necessario vulgatissimum, antiquissimum, et officinale nomen; ergo nec *Ossea*, nec *Mesomora* sed *Cornus* retineri debet. Hisce positis; urgeat Ruppius ex authoritate Rivini, quod *Ossea* sit distinctum genus; *Rudbeckius*, quod *Mesomora*, cum herba sit, reliquae arbores; positis (non concessis) hisce, non licet vocare *Mesomoram Osseam*, vel vice versa, sed debet fingula retinere nomen quod antea gessit.

CENTAURIA. g. pl. 676 sic divisum.

TOURNEFORTIO	VAILLANTIO etc.	PONTEDERAE
Centaur, maj. T.	Rhaponticum T.	Cent. maj. Pn.
Jacea	Serratula Rp.	Jacea
	Crupina D.	
	Jacea V.	Cyanoides.
	Crocodilium V.	
	Calcitrapa V.	
	Calcitrapoides V.	
Cyanus	Cyanus	Cyanus.
	Amberboi V.	

Concludo: Cyanoidem Pn. dici debuisse Jaceam:, et Jaceam Pn. *Serratulam.*"

It is evident from the even more lucid discussion of the "Critica Botanica" that not only the official and most common plant, but also the oldest, i. e., the one holding the name previous to Linnaeus' time should be considered the type. Moreover, let it be well understood that the author is speaking of general practice and only cites the case of *Cornus* as an example. Linnaeus wishes then, to go on record as taking the position that anyone splitting up his genera should logically do so in such a way that his genus names go to the plant group that before his time had that name applied to it. And also he insists that the segregates should have the names which they as groups previously had. This seems a rather unusually clear way to solve the problem of Linnaean types. One may argue that Linnaeus cannot force us to discuss pre-Linnaean attitudes of nomenclature, since the evident reason, according to some superficially minded botanists at present for the starting-point of nomenclature to have been put at 1753 is, that we may abandon all botanical nomenclature before that date. Be it remembered, however, that in the 1756 edition of the "Philosophia Botanica" (and the 1790 as well), Linnaeus still held to the rules he outlined before 1753.

The all-important point also is that Linnaeus, even if he did not quote types in each genus as we now do, he did, as a matter of fact, tell us the only obvious and logical way to do so.

We dare state that if his rule were used instead of the haphazard illogical ones of the congresses, over ninety per cent of the Linnaean

genus types could easily be definitely and immediately designated with very little difficulty.

In cases where Linnaeus substituted new names for the older ones in use, he did so because the name itself is objectionable to him as such, either as being non-Latin, barbarous, or inappropriate. We are told elsewhere in the "Philosophia Botanica" why he made such changes, and for which plants he substituted them. Therefore, the type can be determined readily in these cases. The better thinking botanists of today have for some time realized that a knowledge of plants prior to 1753 *is necessary* and to them there will be a minimum of difficulty in logically determining which plant in a genus Linnaeus had in mind when giving the genus a particular name. What else is this except to derive correctly the types of Linnaean genera? I might also call attention to the fact that the many other nomenclatorial rules of the "Critica Botanica" and "Philosophia Botanica" are quite as important for the stability and perfection of our present taxonomy, and that the decrees of voting botanical congresses have not, as a matter of fact, been able to compare in perfection to the principles enunciated by Linnaeus in these works that constitute his *apologia* for what he does in his practical works.

Finally, if we wish to avoid anarchy in botanical nomenclature, we have a right to insist that none but the author of a genus has a right to fix the type. Congresses have at least determined on this principle for present writers, but why anyone with incomplete information can arbitrarily be allowed to select at random Linnaean types by such makeshift methods as the theory of residues, as has been done for many years past, we are absolutely unable to comprehend.

DISTRIBUTION OF THE ALGA, LEMANEA, IN INDIANA

C. MERVIN PALMER, Butler University

Lemanea is one of the fresh water red algae (Rhodophyceae) having a filamentous branching vegetative structure and a prominent generally green reproductive branch often several centimeters long and up to two millimeters thick. These reproductive structures are found often in large groups attached to rocks in streams with a rapid current. Two years ago, the writer reported this alga as having been found in six counties of the state.[1] A more complete study of its distribution has been made since that time.

The present known distribution of Lemanea includes fifteen counties, all of which are in the southern half of Indiana. From the eastern boundary of the state, these counties extend almost to the western boundary. Twenty-four collections or observations have been made by nine different people. The first record for the state was made in 1883 by Dr. L. M. Underwood for Owen County.[2] It is interesting to note that seven of the nine people report Lamanea for that county. There is no other county with more than two records.

The fifteen counties of Indiana in which Lamanea is now known to be present are, from east to west: Franklin, Ripley, Jefferson, Decatur, Jennings, Clark, Shelby, Bartholomew, Jackson, Harrison, Crawford, Monroe, Lawrence, Owen, and Putnam.

Specimens of the alga collected by Dr. L. M. Underwood, Dr. D. M. Mottier, Dr. M. S. Markle, Mr. Charles Deam, Mr. Robert Prettyman and the writer have been placed in the Butler University herbarium. The specimen of Dr. Underwood's material was sent to the writer by Prof. W. C. Muenscher of Cornell University.

While it seems difficult to distinguish between the various species, there apparently are six represented in the Indiana specimens. These six species, together with the location, date of collection, and name of the collector, are:

L. annulata Kütz. Shelby Co., 1932, Prettyman; Owen Co., 1883, Underwood.

L. australis Atk. Harrison Co., 1931, Palmer.

L. catenata Kütz. Owen Co., 1932, Palmer.

L. nodosa Kütz. Bartholomew Co., 1932, Prettyman; Decatur Co., 1932, Palmer; Jennings Co., 1932, Prettyman; Owen Co., 1932, Mottier; Putnam Co., 1933, Palmer; Ripley Co., 1932, Palmer.

L. pleocarpa Atk. Franklin Co., 1932, Palmer; Owen Co., 1932, Prettyman.

L. torulosa Sirodot. Clark Co., 1933, Palmer; Crawford Co., 1931,

[1] Palmer, C. M. The algae, Schizomeris and Lemanea, in Indiana. Proc. Ind. Acad. Sci. 40:111-113. (1930) 1931.

[2] Atkinson, G. F. Notes on the genus Lemanea in North America. Bot. Gaz. 92: 225-242. 1931.

Palmer; Jackson Co., 1930, Palmer; Jefferson Co., 1925, Markle; Jennings Co., 1930, Deam; Lawrence Co., 1930, Palmer; Owen Co., 1923, Bladyes.[3]

All of the six species are of the Eu-Lemanea group, there being none of the subgenus Sacheria.

The genus Lemanea seems not to have been found as yet in Michigan and Illinois. There are a few records of it in Kentucky and Ohio. Its present known distribution in Indiana is in agreement with the usual statement concerning the habitat of the plant, that is, that it tends to be restricted to streams with a swift current, which are of course frequent in the hilly area of the state.

ALGAE OF INDIANA: SECOND LIST OF ADDITIONS TO THE 1875-1928 CHECK LIST

C. MERVIN PALMER, Butler University

The original check list of Indiana algae was published in volume 38 of The Proceedings of the Indiana Academy of Science;[1] and in volume 40 a list of additions was published.[2] Since then four more papers listing algae of the state, which were published before 1928, have been found. Three counties (Franklin, Vanderburgh, and St. Joseph) not represented in the original check list nor the first additional list have algae recorded for them. Several species are new for the check list.

The discovery of these four papers brings the total notations of algae for Indiana to 894, published up to and including 1928. Since 1928, however, several papers have appeared giving algae of various counties of the state and as a result we now have a total of 2,105 notations. Since 1928, the number of counties represented has increased from twenty-two to forty-three, although thirteen of these have only one alga apiece. The counties with the largest number of notations of algae to date are: Monroe Co. 489, Vigo Co. 320, Marion Co. 303, Morgan Co. 153, and Marshall Co. 135. No other counties yet have over 100 entries. Such counties as Brown, Madison, Steuben, and Carroll are still in the zero column.

Three more corrections should be made to the original check list: page 110, line 13, the phrase **"Cylindrocapsa.** *C. geminella.* Monroe Co. 1909" should be removed to page 117 between lines 15 and 16; page 119, line 19, change **"Spaerocystis"** to **"Sphaerocystis"**; page 117, line 37, change date after "Morgan Co." from "1910" to "1913." In the (1930) 1931 additions to the check list, the following correction should be made: page 107, in map (Fig. 1), place a figure "1" in Owen Co.

[3] Smith, B. H. The algae of Indiana. Proc. Ind. Acad. Sci. 41:177-206. 1931 (1932).

[1] Palmer, C. M. Algae of Indiana—A classified check list of those published between 1875 and 1928. Proc. Ind. Acad. Sci. 38:109-121. 1928 (1929).

[2] Palmer, C. M. Algae of Indiana: Additions to the 1875-1928 check list. Proc. Ind. Acad. Sci. 40:107-109. (1930) 1931.

The algae of Indiana recorded in the four additional papers are given in the following classified list:

ALGAE OF INDIANA—ADDITIONS TO THE 1875-1928 CHECK LIST

GROUP 1. BLUE GREEN ALGAE (CYANOPHYCEAE): (NO ADDITIONS)

GROUP 2. DESMIDS

Closterium. St. Joseph Co. 1909. **Cosmarium.** *C. bioculatum* Breb. St. Joseph Co. 1909. *C. botrytis* Menegh. St. Joseph Co. 1909. *C. costatus* Wolle. Franklin Co. 1885. *C. intermedium.* St. Joseph Co. 1909. *C. pseudobroomii* Wolle. Franklin Co. 1885. **Penium.** *P. margaritaceum.* St. Joseph Co. 1909. **Staurastrum.** *S. polymorphum* Breb. St. Joseph Co. 1909. *S. rugulosum* Breb. St. Joseph Co. 1909.

GROUP 3. DIATOMS

Asterionella. Vanderburgh Co. 1913. **Cocconeis.** *C. pediculus.* Franklin Co. 1885. **Cyclotella.** *C. menighiniana* Vorce. Franklin Co. 1885. **Cymatopleura.** *C. solea.* Franklin Co. 1885. **Cymbella.** *C. gastroides* Van Heurck. Franklin Co. 1885. *C. helvetica* Van Heurck. Franklin Co. 1885. *C. lanceolata* Ehr. Franklin Co. 1885. **Dimenigramma.** Franklin Co. 1885. **Epithemia.** *E. gibba.* Franklin Co. 1885. *E. granulata.* Franklin Co. 1885. **Eunotia.** *E. parallela.* Franklin Co. 1885. **Fragillaria.** *F. ungeriana* Grunow. Franklin Co. 1885. **Gomphonema.** Franklin Co. 1885. *G. acuminatum* Van Heurck. Franklin Co. 1885. *G. capitatum.* Franklin Co. 1885. *G. constrictum* Ehr. Franklin Co. 1885. *G. curvatum.* Franklin Co. 1885. *G. dicotoma.* Franklin Co. 1885. *G. geminatum.* Franklin Co. 1885. *Homeocladia* **(Nitzschia).** *H. sigmoidea.* Franklin Co. 1885. **Meridion.** *M. constrictum.* Franklin Co. 1885. **Navicula.** *N. affinis.* Franklin Co. 1885. *N. amphirynchus.* Franklin Co. 1885. *N. angustata.* Franklin Co. 1885. *N. borealis* Ehr. Franklin Co. 1885. *N. cryptocephala.* Franklin Co. 1885. *N. dicephala* Vorce. Franklin Co. 1885. *N. lanceolata* Pritch. Franklin Co. 1885. *N. obtusata.* Franklin Co. 1885. *N. placentula.* Franklin Co. 1885. *N. timodis.* Franklin Co. 1885. *N. viridis.* Franklin Co. 1885. **Nitzschia.** *N. amphioxis.* Franklin Co. 1885. *N. bicephala.* Franklin Co. 1885. *N. vivax.* Franklin Co. 1885. *Pinnularia* **(Navicula).** *P. major.* Franklin Co. 1885. *Pleurosigma* **(Gyrosigma).** *P. spencerii.* Franklin Co. 1885. **Rhabdonema.** *R. minuta.* Franklin Co. 1885. **Surirella.** *S. limosa.* Franklin Co. 1885. *S. linearis.* Franklin Co. 1885. *S. minuta.* Franklin Co. 1885. *S. ablonga.* Franklin Co. 1885. *S. ovata,* var. *minor.* Franklin Co. 1885. **Synedra.** *S. arcus.* Franklin Co. 1885. *S. obtusa.* Franklin Co. 1885. *S. parallelogram.* Franklin Co. 1885. **Tabellaria.** Franklin Co. 1885. *Tryblionella* **(Nitzschia).** *T. gracilis.* Franklin Co. 1885.

GROUP 4. ALL OTHER ALGAE (CHLOROPHYCEAE, PIGMENTED FLAGELLATA, ETC.)

Bulbochaete. St. Joseph Co. 1909. **Ceratium.** *C. macroceras* Schrenk. Marshall Co. 1918. *C. tripos.* Kosciusko Co. 1918. **Chaetophora.** *C. elegans* Ag. St. Joseph Co. 1909. **Dinobryon.** Marshall Co. 1918. **Draparnaldia.** *D. glomerata* (Vauch.) D. C. St. Joseph Co. 1909. **Euglena.** *E. viridis* Ehrenberg. Marshall Co. 1918. **Mougeotia.** *M. mirabilis* Al. Br. St. Joseph Co. 1909. *M. scalaris* Hass. St. Joseph Co. 1909. **Oedogonium.** St. Joseph Co. 1909. **Palmella.** *P. hyalina* Breb. 1909. **Peridinium.** *P. tabulatum* (Ehrenberg). Marshall Co. 1918. **Spirogyra.** *S. tenuissima* (Hass.) Kütz. St. Joseph Co. 1909. **Vaucheria.** *V. dichotoma* (Lyngb.) Ag. St. Joseph Co. 1909. *V. geminata* (Vauch.) D. C. St. Joseph Co. 1909. *V. sessilis* (Vauch.) D. C. St. Joseph Co. 1909. **Volvox.** *V. aureus* (Ehrenberg). Marshall Co. 1918. **Zygnema.** *Z. insigne* (Hass.) Kütz. St. Joseph Co. 1909.

BIBLIOGRAPHY

(Titles Additional to the Original Check List and First Supplement)

1. 1885. Grahn, E. G. Microscopical Notes. Bull. Brookville (Ind.) Soc. Nat. Hist. No. 1:39-41.

2. 1909. Nieuwland, J. A. Resting spores of Cosmarium bioculatum, Breb. Am. Midland Nat. 1:4-8.

3. 1913. Durbin, W. H. Micro-Organisms in water at Evansville. Engineering Record 67:676.

4. 1918. Evermann, B. W. and Clark, H. W. Notes on certain protozoa and other invertebrates of Lake Maxinkuckee. Proc. Ind. Acad. Sci. 28:236-244.

NOTES ON INDIANA GRASSES, 1932

J. E. POTZGER, Butler University, Indianapolis

This is the first contribution of a series of annual reports on Indiana grasses previously unreported for the counties specified.

The nomenclature is that of Deam's Indiana Grasses, 1929.

The writer also gratefully acknowledges the checking of the species listed here by Mr. C. C. Deam. A specimen of each grass enumerated was deposited in the Butler University herbarium.

Agrostis hiemalis (Walter) BSP. DUBOIS COUNTY. Upland shady woods on Mr. August Mauntel's farm, about six miles southwest of Holland. MONROE COUNTY. Open waste land on Mr. Wm. Baxter's farm, ten miles southwest of Bloomington, Salt Creek Township.

Agrostis perennans (Walter) Tuckerman. HANCOCK COUNTY. Shady ravine, a beech-maple woods about a half mile west of McCordsville. LAWRENCE COUNTY. Along old road in an upland hardwoods. Two miles northeast of Tunnelton. MARION COUNTY. Moist shady hardwoods. Ten miles north of Oaklandon. MORGAN COUNTY. Wooded areas on cliff, also in shady places in a road cut. Five miles south of Martinsville. WASHINGTON COUNTY. Shady upland woods. Three miles south of Kossuth.

Alopecurus ramosus Poiret. DUBOIS COUNTY. Along streams, in waste open places. Found very common in the Dillons Woods area.

Andropogon virginicus Linnaeus. CRAWFORD COUNTY. Waste, open fields on the Marengo Cave grounds.

Aristida longespica Poiret. GREENE COUNTY. Open waste fields along roadsides. Ten miles southwest of Bloomington. LAWRENCE COUNTY. Open waste fields. Three miles northeast of Tunnelton. Growing in dense colonies.

Brachyelytrum erectum (Schreber) Beauvois. DUBOIS COUNTY. Dense upland woods, shaly soil. One mile west of St. Anthony.

Bromus commutatus Schrader. DUBOIS COUNTY. In fields, along roadways and ditches. Near Dillons Woods. MONROE COUNTY. Along ditches, edges of fields. Salt Creek Township, ten miles southeast of Bloomington.

Bromus tectorum Linnaeus. LAWRENCE COUNTY. Along railway embankment near Mitchell. MONROE COUNTY. Along ditches, edges of fields. Salt Creek Township, ten miles southeast of Bloomington.

Cinna arundinacea Linnaeus. CLAY COUNTY. Low wet ground. Twelve miles northeast of Linton. CRAWFORD COUNTY. Low places along stream. HANCOCK COUNTY. Open waste places in lowland woods. Half mile west of McCordsville.

Digitaria sanguinalis (L.) Scopoli. CRAWFORD COUNTY. On rocky sparsely vegetated uplands, waste fields, roadsides. On Marengo Cave grounds. DUBOIS COUNTY. Along railway tracks, roads. One mile

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

west of St. Anthony. MARION COUNTY. Open fields, waste places, roadsides. Ten miles north of Oaklandon.

Echinochloa crusgalli. (L.) Beauvois. DUBOIS COUNTY. Low ground in an open waste meadow. One mile west of St. Anthony. LAWRENCE COUNTY. Low wet place along old road in woods. Two miles northeast of Tunnelton.

Eleusine indica (L.) Gaertner. LAWRENCE COUNTY. Along railway tracks near Fort Ritner. MONROE COUNTY. Waste places along road near Cedar Cliffs.

Elymus canadensis Linnaeus. HANCOCK COUNTY. Along railway track close to ditch. Three miles west of McCordsville.

Elymus riparius Wieg. LAWRENCE COUNY. Along edges of upland field. Three miles northeast of Tunnelton.

Elymus striatus Wildenow. WASHINGTON COUNTY. In upland woods. Three miles south of Kossuth.

Eragrostis pectinacea (Michaux) Nees. LAWRENCE COUNTY. Along railway tracks, sandy waste soil. Near Fort Ritner.

Eragrostis spectabilis (Pursh) Steudel. LAWRENCE COUNTY. Along an old road in shady woods. Also common in open fields. Two miles northeast of Tunnelton. WASHINGTON COUNTY. In open meadow. Three miles south of Kossuth.

Festuca elatior Linnaeus. MONROE COUNTY. Edge of narrow woodland road, rich alluvial soil along Allen Creek. Ten miles southeast of Bloomington.

Festuca octoflora Walter. DUBOIS COUNTY. Along open banks of streams, waste fields. Common in the Dillons Woods area.

Festuca octoflora var. *tenella* (Wield) Fernald. MONROE COUNTY. Open waste places on hillsides. Salt Creek Township. Near Mr. Wm. Baxter's farm.

Glyceria plicata Fries. Wet low ground, *Typha associes* along country road. Salt Creek Twp., Monroe County, 10 miles southeast of Bloomington.

Glyceria striata (Lamarck) Hitchcock. DUBOIS COUNTY. Along a low area of an old creek bed. Mr. August Mauntel's farm, six miles southwest of Holland.

Hordeum pusillum Nuttall. SPENCER COUNTY. Waste places along the road. Very obnoxious weed. Lincoln Memorial ground.

Leersia lenticularis Michaux. LAWRENCE COUNTY. Low swampy ground along Monon railway track near Fort Ritner.

Leersia oryzoides (Linnaeus) Swartz. MARION COUNTY. Muddy bottom of permanently wet ditch. Ten miles north of Oaklandon.

Leersia virginica Wildenow. HANCOCK COUNTY. Lowland woods along edge of intermittent creek. Half mile west of McCordsville. LAWRENCE COUNTY. Shady places along old road in open woods. Two miles northeast of Tunnelton. MORGAN COUNTY. Along edge of ditch, shady places. One mile south of Waverly.

Leptochloa filiformis (Lamarck) Beauvois. CRAWFORD COUNTY. In garden lot at Marengo.

Muhlenbergia mexicana (L.) Trinius. LAWRENCE COUNTY. Shady waste places along old road. Two miles northeast of Tunnelton. MARION COUNTY. Shady moist woods. Ten miles north of Oaklandon.

Muhlenbergia Schreberi J. F. Gmelin. HANCOCK COUNTY. Lowland woods half mile west of McCordsville. LAWRENCE COUNTY. Along shady road through open woods. Two miles northeast of Tunnelton. MARION COUNTY. Shady moist woods. Ten miles north of Oaklandon.

Muhlenbergia sobolifera (Muhlenberg) Trinius. CRAWFORD COUNTY. Rocky sparsely vegetated uplands on Marengo Cave grounds.

Panicum capillare Linnaeus. HANCOCK COUNTY. Open waste places in lowland woods and in fields. Ten miles north of Oaklandon. LAWRENCE COUNTY. In waste places along old roads in open woods. Two miles northeast of Tunnelton. MORGAN COUNTY. Along side of Highway 37. Five miles south of Martinsville.

Panicum dichotomiflorum Michaux. HAMILTON COUNTY. Along side of road on the Marion-Hamilton county line, near Jose-Dale estate.

Panicum implicatum Scribn. POSEY COUNTY. Open waste places, two miles west of Hovey Lake.

Panicum Gattingeri Nash. MONROE COUNTY. Low waste place, fallow field in Salt Creek Twp. Ten miles southeast of Bloomington.

Panicum philadelphicum Bernhardi. MONROE COUNTY. Along creek in Cascade Park. Rich alluvial soil. One mile north of Bloomington.

Panicum virgatum Linnaeus. HARRISON COUNTY. Along side of road, dry clay uplands. Three miles west of Salisbury.

Paspalum circulare Nash. DUBOIS COUNTY. Low moist meadow near edge of woods. One mile west of St. Anthony.

Paspalum pubescens Muhlenberg. LAWRENCE COUNTY. Along edge of road, waste places. Three miles northeast of Tunnelton. MARION COUNTY. Open dry hillside, waste ground. Ten miles north of Oaklandon.

Phleum pratense Linnaeus. POSEY COUNTY. Along side of road. Two miles west of Hovey's Lake.

Poa compressa Linnaeus. DUBOIS COUNTY. In yard of Mr. August Mauntel's farm. Six miles southwest of Holland.

Poa annua Linnaeus. MORGAN COUNTY. Along ditches in the Grassy Fork Fish Hatchery grounds, Martinsville.

Poa pratensis Linnaeus. MARTIN COUNTY. Open places in woods and fields. Near Shoals. MORGAN COUNTY. On grounds of the Grassy Fork Fish Hatchery, Martinsville. DUBOIS COUNTY. On farm of Mr. August Mauntel. Six miles southwest of Holland. In a shady place.

Setaria italica var. *Metzgeri* (Körnicke) Hubbard. LAWRENCE COUNTY. In waste places along railway right-of-way near Fort Ritner.

Setaria lutescens (Weigel) Hubbard. DUBOIS COUNTY. Low waste field, half mile west of St. Anthony. LAWRENCE COUNTY. Low meadow, one mile northeast of Fort Ritner.

Setaria virides (L.) Beauvois. MORGAN COUNTY. Along side of rocky cliff. Five miles south of Martinsville.

Sphenopholis obtusata (Michaux) Scribner. POSEY COUNTY. Along upland ditches near Hovey's Lake.

Sphenopholis pallens (Sprengel) Scribner. MORGAN COUNTY. In open places along ditches of the Grassy Fork Fish Hatchery, Martinsville.

A FIELD STUDY OF THE COMMON BARBERRY

WINONA H. WELCH, DePauw University

During the past four years, the author[1] has studied the common barberry, *Berberis vulgaris* L., in a small area near Freedom, Owen County, Indiana. The investigation has concerned the number of sprouts from roots of destroyed bushes, the number of seedlings from seeds of the eradicated shrubs, the growth of sprouts and seedlings, the dissemination of the seeds, and the survival of seedlings from season to season.

The four barberries considered as the parent or original bushes were in a short row (about seven and one-half feet in length) on the south side of a pastured orchard and not far from a house. These shrubs were cut off about three or four inches above the ground, November, 1928. One of the bushes was estimated to be approximately thirty years old. These plants were growing on an upland area which slopes to the south and east. In the old ravine at the base of the slope are two springs, approximately 160-170 feet apart. No bushes have been found on the north-facing slope.

Each spring and fall since May, 1929, the author has visited the area and has carefully searched for seedlings, shoots, and bushes. The data are grouped according to the phases of the work and are arranged chronologically.

Data concerning seedlings and shoots from parent bushes and stumps:

Date	New Seedlings	Surviving Seedlings	Inflorescences on Shoots	Rusted Leaves on Shoots
May, 1929	Hundreds[1]			
Nov., 1929	0	7		
May, 1930	55	1		
Oct., 1930	0	0		
May, 1931	0	0	1[2]	
Nov., 1931	0	0	0	
May, 1932	0	0	78[2]	365[2]
Oct., 1932	0	0	0	0

Parent Bushes. A large number of seeds in the parent area germinated the first growing season following the cutting of the shrubs. A great decrease in germination occurred the next spring, and no seedlings have been observed since that time. Possibly weather conditions have been unfavorable for the germination of any dormant seeds which might remain. Perhaps a large majority of the seeds have germinated.

[1] This investigation has been made in co-operation with W. E. Leer, U. S. Department of Agriculture, State Leader of Barberry Eradication in Indiana.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

During the first year following the destruction of the parent bushes, numerous, healthy shoots were produced by each stump. These have developed into very conspicuous bushes, varying in height from three and one-half to six and one-half feet. The first inflorescence developed on these shoots during the third spring succeeding the destruction of the parents, and the first leaves showing infection with *Puccinia graminis* were noted the next year.

Bushes on the Slopes. Since the barberry bushes on the slopes were younger, (approximately five to ten years of age), than those near the house, it is assumed that the birds may have carried fruits from the parent plants to their roosting places in the trees and shrubs on the slope, or they may have dropped them as they flew to the springs for water. It is also possible that the seeds were discharged from the alimentary canal of the birds or were coughed up and dropped. The bushes, shoots, and seedlings were usually found among the rocks where the fruits and seeds may have lodged or beneath the trees where the birds may have lighted.

In November, 1929, one bush was transplanted by Indiana University to the campus for experimental purposes. During the year 1931, four shoots, ranging in height from two to fifteen inches, were collected from the remaining underground parts of this plant. During this study, no seedlings or other shoots have been observed in this specific area.

Twenty-one large bushes were growing here and there over the south- and east-facing slopes and were located on imaginary radii extending northwest, north, and northeast from each of the springs in the ravine. Inflorescences, fruits, and rusted leaves were found on these plants. In May, 1930, all of these barberry bushes were salted and killed.

In October, 1930, two groups of seedlings, ranging in height from seven to nine inches, were found on the south-facing slope. There were five plants in one group and three in the other. Probably fruit clusters had fallen here and the seeds germinated after lying in the ground for a period of time.

In November, 1931, three shoots, two to twenty inches high, and three seedlings, one to three inches in height, were collected near dead barberry bushes.

No seedlings or shoots have been found since that date. The fruits and seeds, more or less buried, have remained dormant for different periods of time, thus accounting for the variation in the development of the seedlings.

SUMMARY

1. The parent plants of *Berberis vulgaris* were destroyed in November, 1928.

2. The greatest number of seeds germinated the following spring.

[1] No effort was made to count the seedlings because the ground in the vicinity of the parent bushes was carpeted with them.

[2] All inflorescences and rusted leaves were collected as they were counted.

3. A very great decrease in the number of seedlings occurred the second season and no seedlings were noted thereafter.

4. The number of seedlings which survived was exceedingly small in comparison with the number produced.

5. The shoots from the parent stumps developed flowers when they were two years of age.

6. The first infection by *Puccinia graminis* was observed when these shoots were three years old.

7. These shoots grew to a height of three and one-half to six and one-half feet during the four growing seasons.

8. The fruits and seeds have probably been disseminated by birds.

DEPAUW UNIVERSITY ARBORETUM

WINONA H. WELCH, DePauw University

For the purpose of establishing an arboretum and a wild plant sanctuary, the Botany Department of DePauw University has recently acquired an area of twenty acres, commonly known as Monon Springs, one-half mile west of Greencastle, Indiana.

The proximity to the campus, the meandering stream, the springs, the various slopes, the lowland and upland, the rock outcrops, the excellent variety of woody and herbaceous plants, and the presence of representatives of all divisions of the plant kingdom—all of these aid in making this plot a splendid out-door laboratory for the botany classes of the University.

The vegetation is representative of a climax association. An unusually large number of species of plants were growing in this particular area at the time of the purchase. Within the last few months 150 trees, a large majority of which are uncommon in this part of Indiana, have been added.

Extensive plans for the development of the DePauw University Arboretum have been made. It is proposed to introduce as many species of plants native to Indiana, both woody and herbaceous, as will grow in the area. It is hoped that eventually the arboretum may become of considerable scientific value to botanists interested in our native flora, as well as serve the classes of the department in field work.

VAPOR PHASE ESTERIFICATION

FRANK E. DOLIAN and H. T. BRISCOE, Indiana University

This paper presents the results of a study of the effects of anhydrous salts upon esterification in the vapor phase, a subject heretofore unstudied. In fact, there has been very little investigation of this reaction in the presence of any substances which may act catalytically. Edgar and Schuyler[1] found that the vapor phase of the equilibrium-mixture of acetic acid, ethyl alcohol, ethyl acetate, and water contains a noticeably higher percentage of ester than liquid mixtures. Milligan, Chappell, and Reid[2] studied the effect of silica gel upon vapor-phase esterification. They found that the maximum conversion of acid and alcohol to ester and water occurred at a temperature of 150°-200°C. in the presence of this substance. Their yields consistently approached 90 per cent conversion and showed conclusively that the percentage of esterification varies inversely as the rate of passage of the vaporized mixture through the reaction chamber.

EXPERIMENTAL

Materials. Pure acetic acid was prepared by fractional crystallization. The anhydrous salts were prepared by dehydrating the purest salts obtainable in an electric oven, the temperature of which was carefully controlled. The salts were finely powdered and stored out of contact with air until used. The standard sodium hydroxide solution which was used in titrating the unesterified acid was prepared with particular care to exclude carbon dioxide. Its normality was checked preceding each determination. A thorough review of the literature showed that all of the many processes which have been suggested for the production of absolute alcohol claim a product which is 100 per cent alcohol. Attempts to duplicate these processes in our laboratory showed that the most consistently pure product is obtained by the use of calcium oxide.

The action of calcium oxide upon 95 per cent alcohol was thoroughly investigated. It was found that the maximum dehydrating action of lime was obtained by refluxing one litre of 95 per cent alcohol with 300 grams of lime for six hours, distilling off the partially dehydrated alcohol, and refluxing again with 300 grams of lime for a period of three hours. The alcohol was finally distilled from the lime just before use. It was redistilled through a long fractionating column to prevent small particles of calcium oxide from coming over into the distillate. Particular precautions were also taken to carry out the distillations in a moisture-free atmosphere. The quick-lime was prepared by heating a good grade of hydrated chemical lime to dull redness in an electric muffle-furnace at 700°C.

[1] Edgar and Schuyler, J. Am. Chem. Soc., 46:64 (1924).

[2] Milligan, Chappell, and Reid, J. Phys. Chem., 28:872. (1924).

Aldehydes, the most common impurities in ethyl alcohol, were most completely removed by the addition of 2.5 grams of lead acetate with the second portion of lime. This method was found much more efficient than the use of silver nitrate. Amines and other basic substances were removed from the alcohol previous to any treatment with lime. For this purpose 5 ml. of pure sulphuric acid were added to a liter of 95 per cent alcohol, and the mixture was then distilled.

The progress of the dehydration and purification was followed by refractive index readings on a Pulfrich refractometer and by specific gravity determinations. The latter appeared to be the more trustworthy. A series of eight samples of absolute ethyl alcohol prepared by the treatments above described showed an average specific gravity of 0.78523 at 25°/4°C., and an average refractive index of $N_D^{20} = 1.359084$.

Apparatus. The esterification was carried out in an electrically heated quartz tube which was placed inside of an iron pipe (1¼" in diameter). The pipe was covered with a layer of asbestos paper, upon which the heating element was wound. All this was covered with heavy asbestos for insulation. The quartz tube was 770 mm. long and its inside diameter was 23 mm. Its inner surface was glazed. About 70 mm. of the tube protuded from one end of the furnace for the attachment of the necessary condensation fixtures. The temperature of the furnace was varied by means of a resistance placed in series with the current supply. The temperature of the inside of the furnace was measured by a copper-constantin thermocouple. The hot junction was placed between the quartz tube and the iron pipe at a point exactly outside that point of the interior where the vapors first made contact with the anhydrous salt. This furnace was modelled after that used by Milligan, Chappell, and Reid.

Specific gravity was measured by means of an 27 ml. pycnometer. These measurements were made in a (25°C.) constant temperature bath and were calculated with reference to water as unity at 4°C.

Experimental Procedure. A mixture of equivalent amounts of acetic acid and ethyl alcohol was admitted to the furnace through a small capillary sealed to the end of a section of a burette. The rate of flow was regulated by reducing or increasing the pressure on the surface of the liquid in the burette.

The issuing vapors were condensed and collected in a small Erlenmyer flask. A 2 ml. portion was withdrawn and titrated immediately with standard sodium hydroxide solution. Phenolphthalein was used as the indicator. The result of the titration was subtracted from the result of a similar titration on a 2 ml. portion of the starting mixture. This difference, divided by the number of milliliters of the base necessary to neutralize 2 ml. of the starting mixture, gave directly the percentage of acid converted into ethyl acetate. Fifteen grams of the anhydrous salt, an amount well above that theoretically required to combine with all the water formed in the reaction, occupied 250 mm. at the exit end of the furnace.

RESULTS

Preliminary experiments were performed to determine whether or not the empty furnace possessed any promoting activity. Different temperatures and different rates of passing the vapors through the furnace were investigated. The results showed definitely that esterification occurs only at a high temperature and only when the vapors are passed very slowly. The maximum yields of ester were about 3 to 4 per cent. The products of these blank runs gave positive tests with fuchsin-sulphurous acid solution and, therefore, indicated that some oxidation occurred under the conditions employed.

Hydrated aluminum sulphate, containing 18 molecules of water per molecule of the salt, was dehydrated at 200°C. Its promoting activity was then investigated in the manner already described. The results are shown in Table 1. These indicate that the high temperatures and lower rates are more favorable for esterification. The presence of a large excess of salt did not increase the yield significantly.

TABLE 1.

ALUMINUM SULPHATE

No.	Temperature	Rate cc. vapors per min.	Acid esterified
1	175°C.	386	3.92%
2	175	193	2.74
3	175	73	1.57
4	250	386	30.13
5	250	193	42.35
6	250	84	40.13
7*	250	193	44.38

* 35g. anhydrous salt used.

Potassium aluminum sulphate (potash-alum), containing 24 molecules of water per molecule of salt, was also dehydrated at 200°C. As shown in Table 2, the presence of potassium sulphate has little effect upon the extent of esterification, since these results are only slightly higher than those for aluminum sulphate. The slightly greater yields in this case may be due to the ability of the molecules of the double salt to combine with the greater number of molecules of water.

TABLE 2.

POTASSIUM ALUMINUM SULPHATE

No.	Temperature	Rate cc. vapors per min.	Acid esterified
1	175°C.	386	5.29%
2	175	193	7.51
3	175	193	7.07
4	175	93	13.33
5	250	386	30.70
6	250	386	27.01
7	250	193	43.90
8	250	89	47.07

The difference in the effects of chromium sulphate and potassium chromium sulphate, however, is much more pronounced. The best result obtained with the former was only 6.34 per cent of ester. With the latter, yields of 50-60 per cent of ester resulted. (See Tables 3 and 4). These salts, in their hydrated states, contain the same relative amounts of water as the pair, aluminum sulphate and potassium aluminum sulphate. Hence, in this case, we are forced to the conclusion that the presence of potassium sulphate in the molecule increases the promoting activity of the salt.

TABLE 3.

CHROMIUM SULFATE

No.	Temperature	Rate cc. vapors per min.	Acid esterified
1	175°C.	87	0.49%
2	250	87	6.34

TABLE 4.

POTASSIUM CHROMIUM SULPHATE

No.	Temperature	Rate cc. vapors per min.	Acid esterified
1	175°C.	87	6.21%
2	175	87	7.64
3	200	87	16.19
4	250	87	53.82
5	250	87	55.72
6	300	87	48.63
7	350	87	27.52

TABLE 5.

MAGNESIUM SULFATE

No.	Temperature	Rate cc. vapors per min.	Acid esterified
1	175°C.	87	6.31%
2	200	87	9.54
3	225	87	19.07
4	250	87	33.60
5	275	87	47.55
6	300	87	47.80
7	325	87	40.37
8	350	87	33.10

The heptahydrate of magnesium sulphate (Epsom salts) was dehydrated at 200°C. The effect of temperature upon the promoting activity of this anhydrous salt was thoroughly studied. The results are shown in Table 5. The relation between temperature and the extent of esterification is shown in Fig. 1. This curve shows a very decided maximum of approximately 50 per cent of esterification at a temperature near 285°C. This temperature is far above the temperature

at which the molecule loses all of its water of hydration. The heptahydrate loses six molecules of water at 150°C., and the seventh molecule is removed at 200°C. We should expect the dissociation pressure of the hydrated salt to exceed the partial pressure of water vapor in the furnace at a temperature of 285°C. The results indicate that the action of anhydrous salts in promoting esterification is not entirely due to the withdrawal of water.

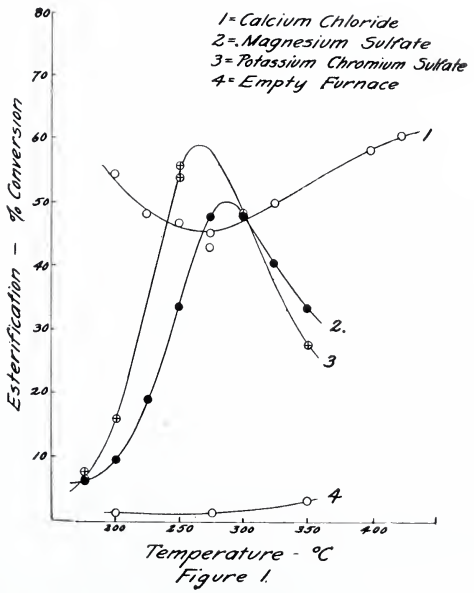


Fig. 1.

The effect of anhydrous, fused calcium chloride was also studied very thoroughly with regard to the effect of temperature upon the extent of esterification in its presence. The temperature-esterification curve for this salt shows a minimum as contrasted with the maxima for magnesium sulphate and potassium chormium sulphate. (See Fig. 1). This minimum occurs at 275°C., at which temperature 45 per cent of the acid is converted into ester (Table 6). This result is difficult to interpret after the results with magnesium sulphate and potassium chromium sulphate. The great affinity which fused calcium chloride exhibits for water vapor, however, might serve as a basis for an explanation of its effect upon vapor-phase esterification. Because of its pronounced hygroscopy, this salt gives a very good yield of ester at relatively low temperatures (up to 175°C.). Above 175°C., however, the combining capacity of the salt toward water vapor is naturally decreased, since at these higher temperatures the dissociation pressure of the hydrated salt exceeds the partial pressures of water vapor in the furnace. At approximately 275°C., which marks the minimum on the curve, the purely catalytic activity of the salt begins to manifest itself.

Since this activity increases up to a certain limit with increasing temperature, the amount of acid esterified increases. It is probable that the curve reaches a maximum somewhere near 425°C., and then falls normally as in the case of magnesium sulphate.

Other anhydrous salts were investigated, but limited time prevented a complete survey of all the possibilities in connection with this

TABLE 6.

CALCIUM CHLORIDE

No.	Temperature	Rate cc. vapors per min.	Acid esterified
1	175°C.	386	48.31%
2	175	193	52.81
3	175	97	54.31
4	200	87	54.52
5	225	87	48.12
6	250	193	36.33
7	250	386	32.60
8	250	63	48.58
9*	250	193	49.44
10	275	87	42.87
11	275	87	45.65
12	275	87	45.29
13	300	87	47.98
14	325	87	50.00
15	400	87	58.03
16	425	87	60.02

* 35g. anhydrous salt used.

TABLE 7.

ESTERIFICATION OF ACETIC ACID BY DIFFERENT ALCOHOLS WITH POTASSIUM CHROMIUM SULFATE AT 250° C.

Alcohol	Rate cc. vapors per min.	Acid esterified
methyl	87	35.84%
ethyl	87	55.72
n-butyl	87	6.01

TABLE 8.

OTHER ANHYDROUS SALTS.

Salt	Temperature	Rate cc. vapors per min.	Acid esterified
Na_2SO_4	250°C.	386	1.11%
$CH_3.COONa$	250	386	1.39
$NaPO_3$	250	87	2.19
$CdSO_4$	250	85	10.78
$ZnSO_4$	250	87	11.24
$MnSO_4$	250	87	11.95
$ZnCl_2$	250	87	39.22
$NiSO_4$	250	87	46.12

reaction. Table 8 shows the highest yields obtained with each of these salts and the conditions under which the yields were obtained. Of these salts nickel sulphate showed the most interesting possibilities and should be further investigated.

Table 7 shows the results of the vapor-phase esterification of acetic acid by three alcohols. These results were obtained at a temperature of 250° C., and in the presence of anhydrous potassium chromium sulphate.

Conclusion

The effects of several anhydrous salts upon the vapor-phase esterification of ethyl alcohol and acetic acid have been studied. It appears that these effects are not due, in every case at least, to the combination of the salt with the water produced by the reaction. No attempt has been made to determine the extent to which esterification might be carried under optimum conditions of temperature, velocity of the vapors, physical state of the salts, etc. The reaction has been studied under conditions which were comparable for each series of experiments attempted.

STUDIES IN ETHERIFICATION

I. THE PREPARATION OF SOME HIGHER ALIPHATIC ETHERS WITH SULFURIC ACID

G. F. HENNION, H. D. HINTON and J. A. NIEUWLAND,
University of Notre Dame

Pure ethers of some of the higher aliphatic alcohols are not, as yet, commercially obtainable products. Needing several of these compounds in our research, a study of the literature was made in an attempt to find a generally satisfactory method of preparation. Of the known methods of synthesis, Williamson's[1] reaction is well known. This reaction has several undesirable features and is mostly of theoretical interest only.

Many other methods of preparation have been proposed since and a few of these will be mentioned. Zeltner and Tarassoff[2] prepared isoamyl ether in 25 per cent yield from sym. dibrom dimethyl ether and isobutyl bromide by the Grignard reaction. Normal amyl ether was prepared by Blaise and Picard[3] from amy iodide and silver oxide. Schroetter and Sondag[4] prepared ethers from the corresponding alcohols using methionic acid as the dehydrating catalyst. In 1852 Williamson[5] reported the preparation of some lower aliphatic ethers from the alcohols using sulfuric acid as the etherification agent. Balard[6] claimed to have used this method successfully in the synthesis of diisoamyl ether. Norton and Prescott[7] disputed the success of the sulphuric acid process and claimed to have obtained only a tar when trying to convert isoamyl alcohol to the ether. A study of the dehydration of alcohols to ethers by means of sulfuric acid was made by Popelier[8]. He reported physical constants of a variety of aliphatic ethers made by him.

In 1921 Hultman, Davis, and Clarke[9] devised a very simple automatic liquid separator which they found useful in a variety of reactions where it was desired to remove water formed by the reaction. With this apparatus they obtained a 60 per cent yield of normal butyl ether from butyl alcohol, using sulfuric acid as a catalyst. The generality of their process in other ether preparations was not reported. Of the known methods of ether synthesis reported in the literature, it was decided to investigate the method of Hultman, Davis, and Clark[9] using the continuous separator.

[1] Ann., **77**:37. (1851).
[2] Ber., **43**:941. (1910).
[3] Ann. chim. phys., 8, **25**:260. (1912).
[4] Ber., **41**. 1921 (1908).
[5] Ann., **81**:73. (1852).
[6] Ann. chim. phys., 3, **12**:294. (1844).
[7] Am. Chem. J., **6**:241. (1884).
[8] Bull. soc. chim. Belg., **32**:179-194. (1923).
[9] J. Am. Chem. Soc., **43**:366. (1921).

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

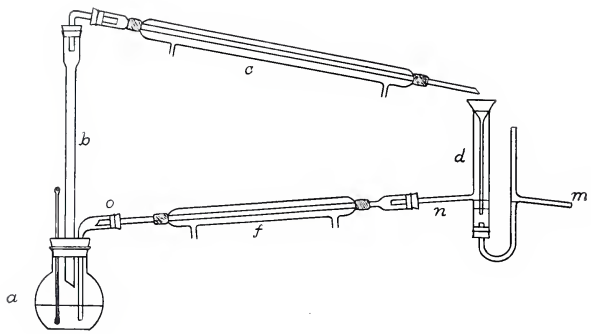


FIGURE 1

PROCEDURE

We have adopted the following procedure and have found it satisfactory for the synthesis of n-butyl ether, n-amyl ether, and isoamyl ether from the corresponding alcohols:

Two mols of the alcohol, previously dried over lime and distilled, were placed in a 600 ml., wide mouth, Florence flask (a in Fig. 1) and 15-20 g. of pure conc. sulfuric acid slowly added. The flask was equipped with a glass delivery tube (b), and a thermometer and adapter (o) both extending into the liquid. The flask and contents were carefully heated over a sand bath. The mixed vapors were carried through the lagged tube (b), condensed in the watercooled condenser (c) and run into the separator (d). Here the condensate separated into two layers. The aqueous layer was automatically removed through the side tube (m) while the ether-alcohol layer was allowed to run back into the reaction flask (a) through the side tube (n), the water-cooled condenser (f) and the adapter (o). In the reaction flask the following reactions take place:

$$ROH + \begin{matrix}HO\\HO\end{matrix}\!>\!SO_2 \longrightarrow \begin{matrix}RO\\HO\end{matrix}\!>\!SO_2 + H_2O$$

$$\begin{matrix}RO\\HO\end{matrix}\!>\!SO_2 + ROH \longrightarrow \begin{matrix}HO\\HO\end{matrix}\!>\!SO_2 + ROR$$

After heating for about one hour a second 15 g. of sulfuric acid was added to the reaction mixture and a third 15 g. portion after heating about two hours.

When the temperature of the reacting mixture had reached a point approximately midway between the boiling point of the alcohol and the ether, the reaction was stopped, the flask disconnected from the apparatus, and the contents thoroughly cooled. About 150-200 ml. of water was added and the mixture transferred to a separatory funnel. The ether layer separated in 10-20 minutes. This was removed, washed once with water, and then three times with 20 per cent sodium hydroxide solution, and finally with 75-100 ml. of water. The washed ether was dried over calcium chloride and distilled, a 20° fraction collected. This fraction was washed again with sodium hydroxide solution, dried over

calcium chloride, and then fractionated. A Snyder three-ball column or an 18″ Vigreux column was used in the final distillation. A fraction boiling within plus or minus one degree of the true boiling point was collected. Yields were 40-65 per cent of the theoretical.

The ethers prepared in this way and their physical constants are shown in Table I.

TABLE I

Ether	Formula	B. P.	n_D^{21}
n-butyl	$(CH_3—CH_2—CH_2—CH_2)_2O$	139-140 745 m.m.	1.4050
n-amyl	$(CH_3—CH_2—CH_2—CH_2—CH_2)_2O$	180-183 738 mm.	1.4175
isoamyl	$((CH_3)_2—CH—CH_2—CH_2)_2O$	170-172 744 mm.	1.4151

DISCUSSION

Popelier[8] records the boiling point of n-amyl ether as 187.9°. The International Critical Tables give the value as 190°. Other values ranging from 169° up are recorded in the literature. The n-amyl ether prepared by the method just described had a boiling point of 180°-183°, a disagreement with any previously reported values. It is possible that the n-amyl alcohol used in the preparation contained impurities which caused the formation of a constant boiling ether mixture.

This work is being continued to extend further the applicability of the process, to investigate other practical etherification catalysts, and to redetermine the physical constants of the higher aliphatic ethers. These results will be published later.

The authors wish to acknowledge and thank Messrs. M. E. Crawford and T. J. Tarasovic for their assistance in carrying out the experiments.

THE ACTION OF ENERGIZERS DURING CASE-CARBURIZATION

E. G. MAHIN and JOSEPH A. TOUSSAINT, Notre Dame

The process of imparting carbon to iron or mild steel by heating the ferrous part, packed in solid carbon, is an old one. Cementation of wrought iron in this way for the production of steel was the only extensive commercial process of steel manufacture until the introduction of the Bessemer process, about 1855, and the low-carbon—and, therefore, ductile—steels are commonly case-hardened by surface cementation, followed by thermal treatment. Gases containing compounds of carbon are employed, in certain instances, as substitutes for solid carbon.

It is now clear that cementation by solid carburizers takes place to only an insignificant extent unless oxygen is available in some form. Ordinarily enough oxygen is contained in the air enclosed with the solid carburizer in the pot to start the necessary reactions but this does not provide for sufficiently rapid carburization and all commercial carburizers contain one or more compounds included in the general class of "energizers."

The only important direct carburizing agent is carbon monoxide. In certain cases hydrocarbon gases are to be considered but the solid carburizers generate only negligible quantities of such compounds. Carbon monoxide is formed as a result of interaction between oxygen and carbon. As the temperature of the carburizing pot rises, carbon dioxide is largely formed, but with further rising temperature the reduction

$$CO_2 + C \rightleftarrows 2CO$$

proceeds, the equilibrium mixture of the two oxides, in presence of carbon, containing nearly 94 per cent of carbon monoxide at 850° C., a common carburizing temperature. At 1000° C. the per cent of carbon monoxide has increased to 99.4, as reported by Rhead and Wheeler.[1]

Carbon monoxide dissolves in the surface layers of iron or steel, reacting then as follows:

$$2\,CO \rightarrow CO_2 + C$$

Carbon so liberated forms a solid solution (austenite), which gives hardening characteristics. Carbon dioxide diffuses to the surface, where it reacts with more carbon to form carbon monoxide, so that a continuous cycle of reactions may take place, involving a given quantity of oxygen. However, in order to carry on the carburization more rapidly, some other agent must be added as an energizer.

If we may suppose that, in a given carburizing pot, approximately one liter of air is enclosed in the interstitial spaces, approximately 200

[1] J. Chem. Soc., 97:2179 (1910).

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

milliliters of oxygen will be so enclosed. Excluding, for the moment, all chemical reactions, thermal expansion due to a rise of temperature from 20° to 850° will have reduced this oxygen content to 52 milliliters, as measured at the initial temperature. There is no change in gas volume due to formation of carbon dioxide but formation of carbon monoxide doubles the volume and, as the pot is never hermetically sealed, expansion from both causes expels gas mixture from the pot so that approximately atmospheric pressure prevails. Assuming the conversion of 94 per cent of the original carbon dioxide to monoxide at 850° (this is slightly altered by the presence of atmospheric nitrogen), the 52 milliliters of oxygen (represented by oxides of carbon) will now have become about 28 milliliters—again, as measured at 20°.

It is easy to see why the rate of carburization may be quite low, with so little oxygen available for these reactions, and energizers which will liberate carbon dioxide when heated will noticeably increase this rate. Energizers commonly used include carbonates of barium, calcium and sodium. The explanation for their action, as commonly accepted, is that they slowly evolve carbon dioxide at carburizing temperatures, and that this reacts with solid carbon to maintain the equilibrium mixture of oxides.

This role of energizers has recently been called into question. Enos[2] carried out a series of experiments, using wood charcoal and pitch coke as bases and a considerable number of carbonates, oxides and miscellaneous substances as energizers. While a detailed analysis of his results would be out of place here, his general conclusions were to the effect that carbonates, as such, are not needed as energizers, but that the oxides corresponding to these carbonates are equally good. He considers it a satisfactory explanation of energizing action to state that added substances act as catalyzers—some good, others not so good and still others as negative catalyzers.

Ragatz and Kowalke[3 4] similarly performed carburizing experiments, using wood charcoal as a base and a considerably larger list of both promising and apparently absurd compounds as possible energizers. They also concluded that the accepted explanation of energizing action is incorrect, with the conclusion that in all such compounds, the activity is a function of the metal itself, the rest of the compound being relatively unimportant. As one proof of this, they cited the case of calcium carbonate, often added to energize commercial carburizing mixtures, but found by them to be practically inert, although it decomposes readily to yield carbon dioxide when heated. (It may be remarked that others disagree with these authors concerning the relative value of calcium carbonate. See the discussion of Enos' paper, already cited.)

Ragatz and Kowalke, in their second paper, offer an ingenious explanation of the action of energizers, involving the discussion of gas concentration gradients and the use of differential equations. They suppose that, at carburizing temperatures, sodium carbonate reacts with carbon as follows:

[2] Trans. Am. Soc. Steel Treating, 20:27 (1932).
[3] Metals and Alloys, 2:290 (1931).
[4] Ibid., 2:343 (1931).

$$Na_2CO_3 + C \rightarrow Na_2O + 2\,CO$$
$$Na_2O + C \rightarrow 2\,Na + CO$$

The sodium so formed is projected as vapor into the gaseous phase, where it reduces carbon dioxide:

$$CO_2 + 2\,Na \rightarrow Na_2O + CO$$

These reactions are thought to be responsible for the excellent properties of sodium carbonate as an energizer.

Barium carbonate also is a very much used energizer but the above explanation does not apply so well to it, on account of the fact that barium does not vaporize.

It seems to the present authors that in the attempt to find a complex explanation of the mechanism of the action of energizers, the authors already cited have overlooked a comparatively simple one. Enos dismisses the whole matter by supposing that added energizers act as "catalysts," the rate of catalysis and the sign, positive or negative, being a specific function of the substance employed. He concludes that a good energizer must be one containing oxygen but offers no explanation for the action of this oxygen. But few chemists are satisfied with a simple statement that a compound is a catalyst, if it is possible to determine what cycle of reactions is involved in the catalysis.

In making a detailed examination of the results reported in all of these papers one is impressed with the fact that generalizations may be made, as follows:

1. The positive energizers are either carbonates or compounds which may form carbonates in presence of carbon dioxide.

2. Of such compounds, the better energizers are those whose carbonates are decomposed—*but decomposed slowly*—at carburizing temperatures. Thus, sodium and barium carbonates or oxides are good energizers, calcium carbonate is a relatively poor one.

3. Certain compounds have no positive action, or they even have a negative one. In the lengthy list of Ragatz and Kowalke, such compounds as thiosulphates, borates and tungstates were found to be ineffective, as might well have been predicted.

4. It may be remarked that where wood charcoal is employed as a carburizer base, the presence of considerable quantities of potassium and sodium carbonates in the ash cannot be ignored. These are themselves excellent energizers.

In the discussion of the earlier portion of the present paper, we attempted to show that if we rely upon pure carbon and the air normally enclosed in the carburizing pot, carburizing action is very slow, largely because by the time carburizing temperatures are attained the available oxygen is relatively small in quantity, thermal expansion and increase in volume due to formation of carbon monoxide having expelled gases from the pot. Since carburization may be effected only by means of carbon monoxide, the concentration of this gas is brought to too low a value for rapid action to take place.

Consider, first, the effect of a slowly decomposable carbonate. As the temperature approaches that at which carburization may take place,

carbon dioxide begins to be evolved from the carbonate. This causes the expulsion of some gas from the pot but the gas mixture so expelled is chiefly atmospheric air, thus replacing a mixture approximately one-fifth oxygen by pure carbon dioxide, each molecule of the latter being equivalent, in potential carburizing power, to one molecule of oxygen. The essential carburizing gas thus rises in concentration, since carbon dioxide is converted, at higher temperatures, into carbon monoxide. However, if the carbonate decomposes too easily and in the lower temperature ranges, its enriching power is too soon spent. Later backward diffusion of air continuously dilutes the carbon monoxide with nitrogen, so that in protracted carburizations the concentration of carbon monoxide drops back continuously toward that which would have prevailed if pure carbon had been employed.

In order that a carbonate may serve as a practical energizer, it should yield its carbon dioxide slowly and over a period extending to several hours. In this manner it will continuously oppose normal dilution by backward diffusing nitrogen.

Consider next the case of the oxide of the metal, corresponding to a given carbonate. At the lowest temperature recorded by Rhead and Wheeler (*loc. cit.*) the equilibrium mixture of the two oxides of carbon, in contact with solid carbon, contains 62.4 per cent of carbon dioxide. This is for a temperature of 650° and there is undoubtedly some oxidation of carbon at still lower temperatures. Such carbon dioxide will partially combine with the metallic oxide, thus disturbing equilibrium between the two gases and resulting in the formation of more carbon dioxide. At the same time absorption of the gas will prevent, to a considerable extent, expulsion of gases from the pot. If the resulting carbonate is one that decomposes at relatively low temperatures, correspondingly small quantities of carbon dioxide will combine with the metallic oxide to form carbonate, while if the carbonate is one which would decompose slowly and only at higher temperatures, it is easily seen that the carbonate formed will act as a reservoir for carbon dioxide (potential carbon monoxide) thus acting exactly as would have been the case if the carbonate, instead of the oxide, had been employed in the first place. In other words, whether we start with carbonate or oxide, we shall have, at a given higher temperature, about the same compound present in either case.

In order to test this hypothesis, two carburizing mixtures were prepared. The carbon base of both was of sugar carbon and this was mixed with 15 per cent of energizer. In one mixture calcium oxide, made by heating calcium carbonate, was the energizer, in the other barium oxide.

These mixtures were heated to various temperatures, enclosed in quartz tubes having one end closed and the other connected with a water seal, to prevent backward diffusion of air. The tubes were heated, in turn, at temperature intervals of 100°, from 400° to 900°. At the end of ten minutes at the stated temperature the contents of the tubes were removed and carbon dioxide determined.

Allowing for the small amount of carbonate found in the original oxides, by a previous analysis, it was found that the carburizer containing calcium oxide increased in carbonate content up to 800°, where

its carbon dioxide content indicated that it was approximately one-fourth converted into carbonate. At 900° carbon dioxide had fallen to about 4 per cent of that corresponding to pure carbonate.

The sample energized with barium oxide contained 6.1 per cent of carbon dioxide at 400° and this steadily increased up to 800°, where conversion was practically complete. At higher temperatures the carbon dioxide content fell somewhat, indicating the gradual decomposition of the carbonate.

So far as these experiments have progressed, the results would seem to confirm the general hypothesis, and to render unnecessary either an accounting for all energizing effects upon the vague assumption of "catalysis," or the setting up of complicated mechanisms, based upon assumed and highly hypothetical reactions.

THE ACTION OF VANADIUM OXYTRICHLORIDE UPON VARIOUS ORGANIC COMPOUNDS

By R. E. Nelson and A. H. McFadden, Purdue University

Since little work has appeared in literature concerning the action of vanadium oxytrichloride with organic compounds, and as it is known to be a very reactive substance, the study of its action on organic compounds should prove of interest.

Snyder and Brown . . . Snyder and Brown, J. Am. Chem. Soc., **47**, 2671 (1925) . . . have studied vanadium oxytrichloride as a solvent. They stated that: "All of the purely organic compound either dissolved, reacted or both; the organic liquids were miscible in all proportions; the liquid aldehydes reacted vigorously; acetone is miscible and reactive as is also acetic anhydride." They do not state procedure details of the work.

Vernon . . . Vernon, J. Am. Chem. Soc. **53**, 3831 (1931) . . . has studied the action of vanadium oxytrichloride upon phenyl magnesium bromide.

Vanadium oxytrichloride, in this investigation, was allowed to react with several representative organic compounds to determine which compounds would be most likely to throw some light on the way in which vanadium oxytrichloride acts.

A summary of these preliminary reactions is given in Table 1.

TABLE I.

The Action of Vanadium Oxychloride with Various Organic Compounds.

	Organic Compound	Action
1.	Acetone	Black viscous precipitate
2.	Benzaldehyde	Black grainy precipitate
3.	Anhydrous benzene	Deep brownish red solution, no evidence of reaction
4.	Anhydrous ether	Deep red solution. No evidence of reaction
5.	Formaldehyde	White precipitate and intense blue solution
6.	Acetophenone	Dark greenish blue solution
7.	Acetaldehyde	Dark green solution
8.	Quinoline	Green stable solid and quinoline hydrochloride
9.	Benzene and anhydrous aluminum chloride	No evidence of reaction
10.	Absolute alcohol	Brown solution with slight evolution of heat
11.	95 per cent alcohol	Yellow orange precipitate of vanadium pentoxide
12.	Melted phenol	Reaction with evolution of hydrogen chloride
13.	Potassium phthalimide	Reacted. One product isolated. Melted at 229° C.
14.	Aniline	Black grainy solid
15.	Monomethyl aniline	Black grainy solid
16.	Dimethyl aniline	Black grainy solid

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

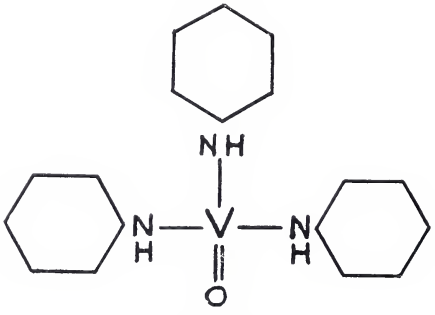
This work has been limited mainly to the study of the action of vanadium oxytrichloride with aniline and with benzaldehyde.

VANADIUM OXYTRICHLORIDE AND ANILINE

Vanadium oxytrichloride reacted with aniline to give a complexity of products, indicating that probably both a condensation and an oxidation had taken place. Aniline hydrochloride along with vanadium dioxide and vanadium tetraoxide have been isolated and identified.

A brownish red organic compound has been isolated and studied. This compound melts at 236° C. and was found to be soluble in ether, benzene, alcohol, concentrated sulphuric acid and concentrated nitric acid. An analysis showed the presence of nitrogen, carbon and hydrogen but no vanadium or chlorine. There was evidence of the presence of an azo group. An analysis for nitrogen by the Kjeldahl method gave 17 per cent. The compound was not identified.

The main product of the reaction, a black solid, was isolated and studied. Great difficulty was encountered in separating it from the oxides of vanadium. The fact that the substance was insoluble in any common reagents made it difficult to purify. Concentrated hydrochloric acid dissolved it and on neutralization with sodium hydroxide, aniline and oxides of vanadium were obtained. An analysis gave 12:5 per cent nitrogen and 16.54 per cent vanadium as compared to 12.24 per cent nitrogen and 14.86 per cent vanadium calculated for the following formula:



The high percentage of vanadium may be due to the difficulty of separating it from the oxides of vanadium.

This compound is a blue-black powder. It has no melting point; on heating it gradually becomes red hot and begins to glow as finely ground coal glows. It finally burns to an ash leaving vanadium pentoxide. On being treated with concentrated nitric acid (two drops on finely powdered solid) it bursts into flame.

VANADIUM OXYTRICHLORIDE AND BENZALDEHYDE

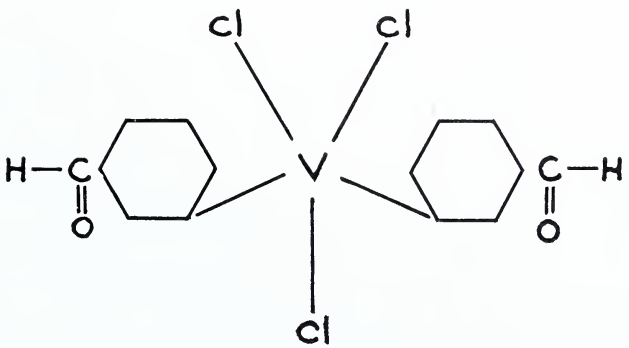
Vanadium oxytrichloride reacted with benzaldehyde to give a fine grainy black precipitate which was easy to filter and wash. This precipitate hydrolyzed on exposure to air, giving off hydrogen chloride and leaving an oily black residue. Benzoic acid and oxides of vanadium

were obtained from the mother liquors. The main product of this reaction proved very difficult to handle since even when in a vacuum dessicator it continued to give off hydrogen chloride gas. Attempts to run an accurate analysis was unsuccessful due to the rapid decomposition. Analysis made on the compound gave the following percentages:

	% Chlorine	% Vanadium
No. 1	23.9	13.4
No. 2	22.4	14.8
No. 3	20.4	14.9

This variation in the percentage of vanadium and chlorine can be accounted for by the fact that the decomposition of this compound caused the percentage of chlorine to drop and the percentage of vanadium to rise.

This product hydrolyzed with water to give benzaldehyde and vanadium pentoxide. A very probable formula for this condensation produce is:



Calculated 13.88 per cent vanadium, 29.0 per cent chlorine.

EXPERIMENTAL

The products of the different reactions were analyzed for vanadium, nitrogen and chlorine.

(a) Analysis for Vanadium.

Two-tenths to 0.5 g. of the sample was accurately weighed and ignited in a porcelain crucible, then cooled and three drops of concentrated nitric acid added to thoroughly oxidize the vanadium to V_2O_5. The crucible was then steadily heated for about an hour to insure thorough ashing. It was weighed as vanadium pentoxide.

(b) Analysis for nitrogen was made by the Kjeldahl method.

(c) Analysis for Chlorine.

The sample was oxidized in a Parr bomb and then determined by the Volhardt method.

THE ACTION OF VANADIUM OXYTRICHLORIDE UPON ANILINE

Twenty cc of vanadium oxychloride was added dropwise to 150 cc (an excess) of aniline dissolved in 200 cc of benzene. The mixture was stirred continuously. Considerable heat was generated. The reaction mixture was steam distilled to remove aniline and benzene. The black precipitate was filtered, dried and extracted in a Soxhlet extractor with benzene. It was dried again and then extracted with hot water to further purify it. The wash waters were found to contain aniline hydrochloride.

This blue black organic vanadium compound had no melting point but gradually became red hot and began to glow like finely granulated coal. On burning vanadium pentoxide remained. On treating the organic compound with concentrated nitric acid it bursts into flame. The analysis was as follows:

	Nitrogen	Vanadium
Calculated for $C_{18}H_{18}N_3VO$.....	12.24	14.86
Found	12.56	16.54

The benzene extract contained a red azo-like compound which was not identified.

Vanadium dioxide and vanadium tetroxide were formed in the reaction and the difficulty of separating these probably accounts for the high value in the analysis for vanadium.

THE ACTION OF VANADIUM OXYTRICHLORIDE UPON BENZALDEHYDE

Ten cc (1 mol) of vanadium oxytrichloride was run, as in the aniline experiment, in to an excess (3 mols) of benzaldehyde in benzene solution. The reaction mixture was stirred an hour, then the precipitate was filtered, washed with ether and put into a vacuum dessicator to dry. Hydrogen chloride was slowly evolved in the dessicator and copiously given off when samples were dried outside the dessicator. The residue after the loss of HCl was a black oily residue. Benzoic acid and oxides of vanadium were obtained from the mother liquors.

Attempts to run an accurate analysis were unsuccessful owing to the rapid hydrolysis.

Analysis	% Chlorine	% Vanadium
Calculated for $C_{14}H_{10}Cl_3VO_2$.....	29.0	13.9
Found	23.9	13.4
	22.4	14.8
	20.4	14.9

The product hydrolyzed with water to give benzaldehyde and vanadium pentoxide.

SUMMARY

1. The reaction between vanadium oxytrichloride and aniline has been studied.

2. The reaction between vanadium oxytrichloride and benzaldehyde has been studied.

3. The reaction of vanadium oxytrichloride with fourteen other organic compounds has been observed.

CHLORINE IN THE LEAD STORAGE BATTERY

R. L. Shelley and O. W. Brown, Indiana University

The manufacturer of lead storage batteries has long been cognizant of the effect of chlorine on his product. Batteries sometimes bubble or "gas" while standing on open circuit, the positive plates become brittle and break up, the separators bleach and become soft and the battery itself loses charge. These phenomena are often correctly attributed to the presence of chlorine.

Chlorine is present in the storage cell only as an impurity and is not found in all or even many cells. It finds its way into the cells through impure battery water, through the use of impure materials of construction and, in rare cases, by the direct addition of salt water where the uninitiated tries to rejuvenate a cell in the same manner in which boys often successfully enliven a worn out dry cell. Its effect remains the same whatever the source of contamination. The purpose of this paper is to demonstrate these effects of chlorine and to point out how, when present, it may be removed.

Experimental

The original acid from a fully charged, five plate, storage cell was replaced with 425 ml. of 1.285 sp. gr. electrolyte to which had been added 8.186 g. of chlorine in the form of sodium chloride. Extremely vigorous gasing and a strong odor of chlorine was noticed immediately. The surface of the electrolyte was whipped into a froth by the escaping chlorine. Forty-five minutes after filling the battery the evolution of chlorine had become much less violent and a 5 ml. sample of the electrolyte was pipetted out for analysis. The method of analysis used in this experiment, as in all succeeding ones, was Volhard's. The electrolyte at this time contained 210.7 mgs. of chlorine per 100 ml. of solution, about one-ninth of the quantity originally present. Similar analyses 3 and 24 hours after the start showed the electrolyte to contain 106 and 22.4 mgs. per 100 ml. respectively. At the end of the 24 hour period the total voltage of the cell on open circuit was 1.84 volts, indicating that the battery was almost completely discharged. The cell was then put on charge and brought up to a condition of full charge at which time it contained no chlorine. Fifty-five ampere hours were required for this purpose, which is within 10 per cent of the capacity of the cell. The separators were bleached on the side next to the positive plates. They were very soft and under light rubbing by the finger tips easily disintegrated. The grids did not seem to be appreciably brittle in this case.

This experiment shows that chlorine in a battery will be eliminated even while the battery is standing on open circuit and that charging increases the speed with which this is accomplished. The bleaching of

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

the separators on the side next the positive plates shows that the liberation of chlorine takes place at this electrode. The reaction resulting in the liberation of chlorine takes place between the combined chlorine and the active material of the positive plates. It is probably the same as that sometimes employed in preparing chlorine in the laboratory.

$$PbO_2 + 2HCl + H_2SO_4 \rightarrow PbSO_4 + 2H_2O + Cl_2$$

The fact that the positive grids did not become brittle in this experiment merely means that the chlorine was not present a sufficient time for this result to become apparent.

The loss of charge noted in this experiment was probably largely due to the reaction of the active material in the positive plates. That the negative plate can also be discharged by the presence of chlorine has long been surmised. According to this idea the chlorine liberated at the positive plate during charge dissolves antimony out of the positive grid. The dissolved antimony is then plated upon the active material of the negative plate and forms a short circuited couple with the negative active material. This short circuited couple discharges the active material of the negative plate. The following experiments were made in order to test this hypothesis.

Seven cells were set up in small glass beakers. The negative plates consisted of pieces cut from previously formed plates. The positive plates were made of solid antimonial lead. These were assembled in 1.200 sp. gr. acid and connected in series. To the first three cells salt was added in sufficient quantities to make 50, 100 and 1000 mgs. of chlorine per 100 ml. of electrolyte, respectively. The last four contained no chlorine. The cells were all given several cycles of charge and discharge at about 0.03 amperes per sq. in. of positive plate surface. A white precipitate appeared in the bottom of the first three cells, the most being in the one containing the most chlorine. In the others a deposit of brown lead peroxide was observed. The negative plates were removed from the acid, washed with distilled water and dried for analysis. A small amount of active material was scraped from each negative plate, care being taken not to remove any of the grid metal. These portions of active material were tested individually for antimony by the Marsh test. The four cells to which no chlorine had been added gave negative tests, while the other three all showed the presence of antimony. The amount of antimony was greater in accordance with the quantity of chlorine in the cells. The first cell, which contained only 50 mgs. of chlorine per 100 ml. of electrolyte, gave only a faint test, yet distinct enough to be plainly seen. Negative active material from the first three cells were also tested for arsenic and negative tests were obtained. This confirms the presence of antimony and proves that the chlorine causes it to dissolve from the positive grid after which the antimony is plated out on the negative active material. The removal of antimony from the positive grid leaves it easily attackable and the subsequent peroxidation of the grid produces mechanical weakness.

These experiments having shown how chlorine effects the storage cell, it was deemed advisable to determine the rate at which chlorine is eliminated from the cell. To this end the following experiments were performed.

To three cells of ordinary starting battery size, containing five plate elements, and whose electrolyte was adjusted to 1.285 sp. gr., 100, 200 and 400 mgs. of chlorine was added respectively, in the form of sodium chloride. The cells were given three cycles of charge and discharge. At the end of the second and third cycles 50 ml. portions of the electrolyte were removed from each cell for analysis. The results of these analyses are recorded in Table I.

TABLE I

Cell No.	Mgs. of combined chlorine per 100 ml. electrolyte		
	Start	End 2nd cycle	End 3rd cycle
1.	400	0.38	0.00
2.	200	0.22	0.00
3.	100	0.37	0.00

It is evident from this experiment that various amounts of chlorine are eliminated from batteries, by charging and discharging, in practically the same time so long as the quantities present are not great. By the end of the second cycle more than 99.9 per cent of the chlorine had been liberated, while all of it had disappeared by the end of the third cycle. From this it may be concluded that no battery in active service can long contain combined chlorine as chloride unless it has a constant source of contamination.

To these same cells, now fully charged and free from chlorine, sufficient salt was added to introduce 1000 mgs. of chlorine into each cell. This is approximately 200 mgs. per 100 ml. of electrolyte. The cells were then allowed to stand on open circuit and the electrolyte was analyzed at various times. The results are given in Table II.

TABLE II

Cell No.	6 days after start		10 days after start		14 days after start	
	mgs. present	% eliminated	mgs. present	% eliminated	mgs. present	% eliminated
1.....	3.2	98.4	0.56	99.7	0.46	99.77
2.....	1.4	99.37	0.48	99.75	none	100.0
3.....	1.26	99.4	0.77	99.6	none	100.0
Ave.....	1.95	99.0	0.60	99.7	0.15	99.92

This shows that the rate at which the last traces of chlorine are eliminated is extremely low. That is, the rate at which chlorine is evolved is proportional to the concentration of chlorine ions in the electrolyte. This was to have been expected from a consideration of the law of mass action. The reaction may also be expected to run to completion since the chlorine is liberated as a volatile product.

Other experiments were conducted showing that the rate of elimination is lower in stationary batteries where the gravity of the electrolyte is only about 1.210. Still other experiments were made demonstrating that when chlorine is added in the form of ammonium chloride it acts in the same way and is eliminated at about the same rate. In these latter experiments brittle positive grids were encountered.

General Discussion

Chlorine when present in the storage battery, enters into a reaction with the lead peroxide of the positive plates, the reaction resulting in the discharge of the plate and the release of free chlorine. The chlorine, being given off at the positive plate comes in contact with the separators on the side toward these plates. The free chlorine bleaches the separators, at the same time causing them to lose their hardness, toughness and tensile strength, thus diminishing their life.

Most of the free chlorine escapes from the battery, but a portion of it comes in contact with the antimony in the positive grid and dissolves it. During charge the chlorine ions liberated on the positive grid also dissolve antimony. This dissolved antimony is carried to the negative plate where it is plated out in a spongy form, thus forming a short circuited couple with the lead sponge, which discharges the plate. As the positive grid is depleted in antimony it becomes peroxidized and very brittle.

If the contaminated cell is allowed to stand on open circuit all of the chlorine is apparently eliminated. The rate at which this liberation takes place is dependent on the concentration of combined chlorine in the electrolyte. This rate may be greatly accelerated by charging and discharging.

Conclusions

The foregoing experiments show that:

1. Chlorine reacts with the lead peroxide in the positive plate causing its discharge and the release of free chlorine.
2. Chlorine dissolves antimony from the positive grid causing it to become easily peroxidized and lose its mechanical strength.
3. The dissolved antimony is plated out on the negative plate where it forms a short circuited couple and discharges the plate.
4. Chlorine bleaches the separators, at the same time causing them to lose their hardness, toughness and tensile strength, thus diminishing their life.
5. Chlorine is released from the surface of the positive plate as free chlorine.
6. The rate at which chlorine is released depends upon the concentration of combined chlorine in the electrolyte.
7. The rate at which chlorine is released may be greatly accelerated by charging and discharging.
8. Chlorine is eliminated from batteries with high gravity electrolyte at a greater rate than from batteries with low gravity electrolyte.

BORON FLUORIDE IN ACETAL CATALYSIS

THOMAS H. VAUGHN, University of Notre Dame

A new method of making acetals from acetylene and hydroxy compounds, using boron fluoride and mercuric oxide as catalysts was reported by Nieuwland, Vogt, and Foohey[1] in 1930. Their work, and that of other investigators[2] has shown that in most instances this new procedure is superior to the older methods of synthesis. This method has also been used in these laboratories for the preparation of ketals from hydroxy compounds and substituted acetylenes.[3]

In 1931, Vaughn, Bowlus, and Nieuwland[4] advanced a formula for the acid formed by the union of boron trifluoride and alcohol and proposed a mechanism to explain the function of this acid in acetal catalysis. The coordination structure assigned to the acid has recently been confirmed by the work of Sugden and Waloff[5] on the parachors of additive compounds of boron fluoride.

In applying this new method of synthesis it has been customary to use 2-5 grams of boron fluoride for each 100 grams of hydroxy compound which was to be ethylidinated. The purification of the resulting acetal has in some instances been complicated by the presence of these large amounts of boron. That the concentrations of boron fluoride used were unnecessarily high is shown by the instance reported by Nieuwland, Vogt, and Foohey[1] where .142 g. of boron fluoride was sufficient to catalyze 200 g. of glycerol to the acetal. Since it was felt that even this concentration was unduly high the present work was undertaken to determine the minimal amount of boron trifluoride necessary for the formation of glycol acetal from glycol and acetylene.

EXPERIMENTAL PART

Materials. The acetylene was obtained from a 40 cu. ft. Prest-O-Lite cylinder and was used without purification. Ethylene glycol was obtained from The Eastman Kodak Company and boiled at 198-200° C. The mercuric oxide was Baker's C.P. red powder. Boron fluoride was prepared from boric anhydride, calcium fluoride and sulfuric acid and was purified by passing through columns of sodium fluoride and fused boric oxide.[6] Glycol acetal was prepared by the action of acetylene on glycol[1] and was carefully purified by repeated fractionation.

[1] Nieuwland, Vogt and Foohey, J. A. C. S. 52:1018-24 (1930).

[2] Hinton and Nieuwland, J. A. C. S. 52:2892-6 (1930). J. A. Nieuwland U. S. Pat., 1,824,963 Sept. 29, 1931.

[3] The results of this work will be discussed in a later communication.

[4] Vaughn, Bowlus and Nieuwland, Proc. Ind. Acad. Sci., 40:203-6 (1931).

[5] Sugden and Waloff, J. Chem. Soc., 1932, 1492-96.

[6] Bowlus, "The Action of BF_3 on Organic Compounds," Thesis University of Notre Dame (1931).

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

Preparation of Boron Trifluoride Solutions. Two hundred grams of powdered boric anhydride was well mixed with 400 gm. of powdered calcium fluoride contained in a 3-1. Erlenmeyer flask. Thirteen hundred grams of concentrated sulfuric acid was then added and the mixture gently heated with a Bunsen burner. After the evolution of gas had continued for about 30 minutes, the stream of gas was purified as above described and passed into an accurately weighed amount (25-30 ml.) of ethylene glycol contained in a 50 ml. volumetric flask, the flask being cooled in cold water during the absorption. When about 5 grams of boron fluoride had been absorbed the flask was again weighed and the solution made up to 50 ml. The concentration of the solution was calculated as grams per milliliter. By careful dilution a series of solutions containing lesser amounts of boron fluoride was prepared.

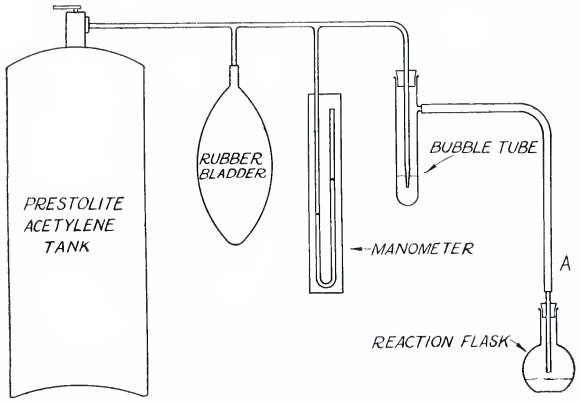


FIGURE 1

Apparatus. The apparatus used in making the determinations is shown in Figure 1. The bladder was a small size swimming tube which was capable of standing pressures up to 150 mm. of mercury. The entering tube of the bubble counter was drawn out to a very fine capillary so that even a very small absorption of gas in the reaction flask could be detected. Ethylene glycol was the liquid used in the bubble counter. Small Florence flasks (150 ml.) were used as reaction vessels. All joints between rubber tubing and glass were securely wired to prevent leaks.

Procedure. Nineteen milliliters of ethylene glycol was measured into the reaction flask from a burette which was allowed to drain for five minutes. 0.30 gram of red mercuric oxide was added to the glycol and the flask connected to the absorption apparatus which had been previously washed with acetylene until free from air. The needle valve on the acteylene cylinder was opened and the pressure in the system raised to 100 mm. of mercury. The stopper was loosened and the flask flushed out with acetylene until the pressure had dropped to 80 mm. The stopper was replaced and the pressure was raised to 100 mm. The flask was then shaken until the glycol was saturated with acetylene. Satura-

tion usually required about 10 minutes and was indicated by the cessation of the flow of bubbles in the bubble counter.

The acetylene supply was shut off at A by means of a pinch clamp and the stopper removed. One milliliter of a solution of boron fluoride in glycol of known concentration was added to the flask from a pipette and the flask flushed out as before until the pressure fell to 80 mm. The pressure was again raised to 100 mm. and the reaction flask shaken. Catalysis was indicated by a gradual increase in the rate of absorption as indicated by the flow of bubbles through the bubble counter and by the formation of a grey deposit on the bottom of the flask. Solutions containing decreasing amounts of boron fluoride were then used in the determination until the signs of catalysis could no longer be observed.

One milliliter of catalyst was used in each run. This, with the 19 ml. of glycol used, gave a total volume of 20 ml. in each run. The results of a number of such runs are listed in Table 1.

TABLE 1.

Glycol in ml.	HgO in gms. ∓ .019	g. BF_3/ml. Catalyst	g. BF_3/ml. Reaction Mix.	Catalysis
20	.300	.1455	.00727	+
20	.300	.01455	.000727	+
20	.300	.01164	.000582	+
20	.300	.00873	.000436	+
20	.300	.00582	.000291	+
20	.300	.00291	.0001455	+
20	.300	.001766	.0000883	+
20	.300	.001513	.0000756	+
20	.300	.001455	.0000727	+
20	.300	.001397	.0000698	+
20	.300	.001222	.0000611	+
20	.300	.001134	.0000567	+
20	.300	.001047	.0000523	+
20	.300	.000960	.0000480	—
20	.300	.000873	.0000436	—

To determine whether or not boron fluoride must be present in a certain molal ratio to glycol several determinations were made with mixtures of glycol and glycol acetal. The results of these experiments are shown in Table 2.

TABLE 2.

Glycol in ml.	Glycol Acetal in ml.	HgO in g. ∓ .019 g.	g. BF_3/ml. Catalyst	g. BF_3/ml. Reaction Mix.	Catalysis
10	10	.300	.001047	.0000523	+
10	10	.300	.000960	.0000480	—
10	10	.300	.000873	.0000436	—

DISCUSSION

These experiments show that $(50 \mp 2)\ 10^{-6}$ g. of boron fluoride per ml. of glycol is sufficient to catalyze the formation of glycol acetal from acetylene. They also show that the same amount is required to initiate catalyses in a mixture consisting of 50 per cent glycol and 50 per cent glycol acetal. These results show that catalysis does not depend on the mole ratio of boron fluoride to glycol, which was 1 to 234,000 in the glycol and 1 to 117,000 in the glycol glycol-acetal solution, but rather on the concentration of boron fluoride.

In the published procedures for the preparation of acetals from acetylene concentrations of about .25 g. of boron fluoride per gram of hydroxy compound have been recommended. The results of the present work show that in the case of ethylene glycol this amount is about 500 times greater than that actually necessary. By using concentrations of catalyst which are near to those actually necessary the isolation and purification of acetals should be materially simplified.

When glycol acetal is prepared by the catalytic method the speed of acetylene absorption increases as the reaction progresses. This increase in speed has been regarded as due to either or both of two causes. First, that as the reaction proceeds, the ratio of boron fluoride to unreacted glycol increases, speeding up the reaction by increasing the relative amount of catalyst present. Second, that as more glycol acetal is formed the effective concentration of acetylene is increased due to its greater solubility in the acetal than in the glycol; the speed of reaction being accelerated by this increased solubility because glycol alone will not absorb acetylene as fast as it can be converted. It was found that in saturating the glycol-glycol acetal mixture with acetylene that much more acetylene was absorbed than by pure glycol and that the absorption was considerably more rapid. This evidence coupled with the fact that very little change in speed of absorption was noticed by greatly increasing the amount of boron fluoride present in the reaction mixture would seem to indicate that the second cause alone is responsible for the increased rate of absorption which has been observed.

The actual role of mercuric oxide as a catalyst in this method of making acetals is not known and has not been taken into account thus far. That it does enter into the reaction is certain since the reaction will not proceed in its absence. Work is under way in this laboratory at present to determine the part played by mercury in the catalysis and to determine the minimal amounts of boron fluoride necessary for the ethylindination of other hydroxy compounds.

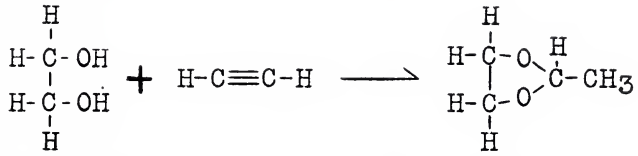
ACKNOWLEDGMENT

The author gratefully acknowledges the assistance of Mr. John R. Voss in the conduction of this work.

THE CATALYTIC SYNTHESIS OF GLYCOL ACETAL

THOMAS H. VAUGHN and J. A. NIEUWLAND, University of Notre Dame

In 1930 Nieuwland, Vogt and Foohey[1] reported that in the presence of mercuric oxide and boron fluoride ethylene glycol and acetylene condense to form glycol acetal in accordance with the following equation.



Glycol acetal has been known since 1861 when it was prepared by Wurtz[2] by the heating of acetaldehyde and paraldehyde with ethylene glycol. It was later shown that the material could be obtained in better yield by the addition of dehydrating agents to the reaction mixture[3]. Hill and Hibbert[4] prepared the material from acetylene using mercuric sulfate and sulfuric acid as catalysts. The method advanced by Nieuwland, Vogt and Foohey[1] has several advantages over the older methods and can be generally applied to hydroxy compounds.

The purpose of this article is to present an improved experimental procedure for the catalytic preparation of glycol acetal. By the use of this improved procedure a ten per cent higher yield and a purer product can be obtained than previously reported. In addition to these advantages the absorption of acetylene consumes less time and requires practically no attention.

MATERIALS

Acetylene was obtained from a 40 cu. ft., Prestolite cylinder and was purified as described in the procedure. Ethylene glycol was obtained from the Eastman Kodak Company and boiled at 198-200°C. The mercuric oxide was of the red variety and was a standard C.P. grade.

Boron fluoride was prepared by the action of sulfuric acid on a mixture of boron trioxide and calcium fluoride. Two hundred grams of finely powdered boron trioxide was intimately mixed with 400 g. of calcium fluoride in a 3-1. Erlenmeyer flask. Thirteen hundred milliliters of concentrated sulfuric acid was added, and the mixture well shaken. Some silicon fluoride which was formed when the acid was added was allowed to escape. The mixture was heated with a small Bunsen flame and the boron fluoride evolved, passed through concentrated sulfuric acid

[1] Nieuwland, Vogt and Foohey, J. Am. Chem. Soc., **52**:1018-24 (1930).

[2] Wurtz, Compt. rend., **53**:378 (1861). Ann., **120**:328 (1861).

[3] Tochert, Ann. chim, phys., (6) **16**, 26, (1889); Clarke J. Chem. Soc., **101**. 1803 (1912).

[4] Hill and Hibbert, J. Am. Chem. Soc., **45**:3113 (1923).

and into methyl alcohol. The absorption flask was kept at 20-5°C. by cooling with ice water. If the heating should be interrupted for any reason, the generator must be vigorously shaken before heating is resumed, in order to break up the cake of calcium sulfate which forms.

PROCEDURE

In a three-necked, 2-1, tarred flask, fitted with an inlet tube, a mercury sealed Benning's stirrer[1], and an outlet tube connected to a rubber bladder and a mercury manometer equipped with contacts for closing a bell circuit (Figure 1), is placed 10 g. of a 55-65 per cent solution

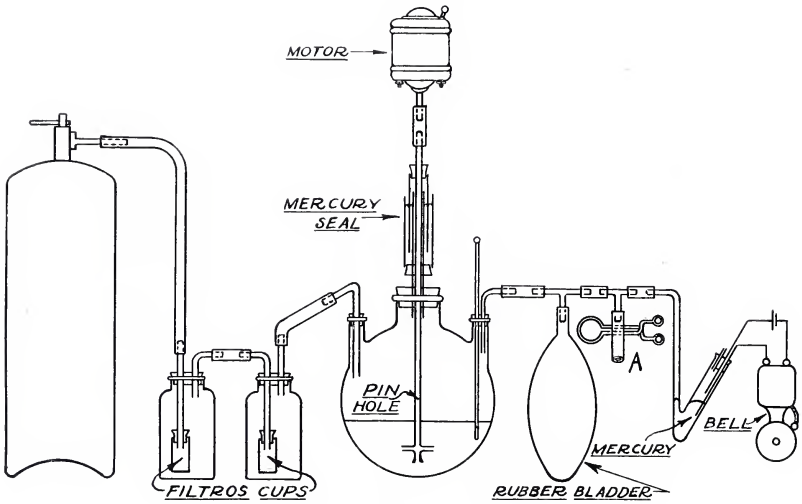


Fig. 1.

of boron fluoride in methyl alcohol, and 4 g. of mercuric oxide. The flask is allowed to stand two minutes until the mercuric oxide is partially dissolved and 248 g. (4 moles) of ethylene glycol added. Acetylene, from a Prestolite cylinder, is washed with water to remove acetone, dried with concentrated sulfuric acid (Note 1) and passed into the flask through the inlet tube. The pinch cock A is opened and the air completely displaced by acetylene. The pinch cock is closed and the stirrer started. The acetylene is rapidly absorbed (Note 2) and there is a considerable evolution of heat. The flask is kept cool (30-50°C.) by immersing it in ice water.

The stirring is continued about three hours, until 100-104 g. (4 moles) of acetylene has been absorbed (Note 3) and the flask is disconnected. The mercury sludge is allowed to settle (Note 4) and the liquid decanted into a separatory funnel. The acetal is washed twice with 100 cc. portions of a 50 per cent solution of potassium carbonate (Note 5) and dried over calcium chloride for two hours. The dried acetal is fractionated through a 3 ft. Vigruex column. The fraction

[1] Benning, Proc. Ind. Acad. Sci., 37:263 (1927).

boiling at 80-3°C. is collected. The yield of glycol acetal is 240-60 g. (67-73 per cent of the theoretical amount based on the acetylene absorbed).

Acetals of other glycols can be prepared by this method.

Notes on Procedure

1. Complete drying is necessary to prevent the formation of acetaldehyde and consequent tarring of the reaction mixture. This can be readily accomplished by spraying the wet gas through a Filtros cup into concentrated sulfuric acid as shown in Figure 1. If desired the water wash may be omitted as the sulfuric acid removes most of the acetone.

2. During the reaction the stream of acetylene is easily regulated by observing the rubber bladder, which should be partially inflated. If this is increasing in size the flow of gas should be diminished and, if decreasing, the flow should be increased. Should the pressure in the flask increase above 4-5 cm. of mercury (contacts should be set for this pressure) the bell rings and calls attention to the fact. Should the warning be ignored the excess acetylene bubbles through the mercury.

3. It is sometimes necessary to add 4 g. portions of mercuric oxide to replace that destroyed by the action of the acetylene. Marked slowing of the reaction indicates that the catalyst is spent.

4. The flask should be tilted as far to one side as possible during the settling in order that the clear liquid can be poured off the sludge without disturbing it. If necessary the contents of the flask should be filtered through cotton.

5. After shaking with the first portion of potassium carbonate solution the lower layer is cloudy due to the presence of insoluble inorganic fluo compounds. Only about two thirds of this should be run out as it is sometimes almost impossible to sharply separate the layers. On addition of the second portion of wash solution the remaining fluoborates dissolve.

Summary

An improved procedure for the synthesis of glycol acetal from acetylene and glycol has been described. By the use of this procedure a 67-73 per cent yield of the pure acetal may be obtained. The procedure requires less time and attention than any previously described.

SOME HILLS OF CIRCUMALLUVIATION IN THE LOWER WABASH VALLEY

Marion M. Fidlar, Indiana University

Introduction

The purpose of this paper is to describe in detail two erosion remnants which stand above the broad alluvial floor of the Wabash valley in southwestern Indiana, and to present an explanation of their presence in the region. In addition to the two described, there are many others of similar character in the deeply alluviated floor of the lower Wabash valley. Among these are the Robeson Hills, Dicksburg Hills, Claypole Hills, Foots Pond Hills, Dogtown Hills, Mumford Hills and Gordon Hills. They are regarded as hills of *circumdenudation* and *circumalluviation*. E. T. Cox[1] mentions several of these features in the region of Knox County, Indiana, and attributes them to the resistant power of the Merom sandstone. Malott[2] describes them in a general way and uses the term *island hills* as suggested by Shaw[3]. However, the erosional remnants in the lower Wabash in Indiana have not been described in detail.

In 1931 the writer made a study of these isolated hills in Knox County, Indiana, south of Vincennes. It is certain that these hills of bedrock rising above the alluvial floor of the Wabash valley are features connected with the history of the development of the valley itself. One of the hills studied, known as La Mamelle, is quite small, while the other, known as Chimney Hills, may serve as an example of the larger ones of the region. The author wishes to propose the term *valley braid core* to apply to these and other similar isolated masses formed in the same manner.

The writer wishes to acknowledge the able assistance and criticism rendered him by Dr. C. A. Malott of Indiana University.

Description of the Region

The area in which the features are located is in the southwestern part of Knox County, about seven miles slightly west of south of Vincennes. The old valley floor of the Wabash is approximately flat, from three to seven miles wide, and is bordered by upland hills standing nearly 100 feet above the flood plain. On the Illinois side of the river, the upland bordering the broad valley floor is covered with glacial till

[1] Cox, E. T., Geological Survey of Indiana, **1873**:324.

[2] Malott, C. A., Handbook of Indiana Geology, Indiana Dept. Conservation, **1922**:103-104.

[3] Shaw, E. W., New System of Quaternary Lakes in the Mississippi Basin, Jour. Geol., **19**:481-491, 1911.

and loess, while on the Indiana side it is mantled by wind-blown sands and loessial deposits. The Wabash River swings in broad curves across the deeply alluviated floor of the valley, occasionally touching the eastern or the western sides. In the northern part of Knox County the expansive plain lies for the most part in Illinois, but in the region of investigation it is largely in Indiana. The present Wabash River winds through this floor in a channel twenty feet or slightly more below the general surface of the valley floor, and in the mapped area (Figure 1) it is near the western side of the valley.

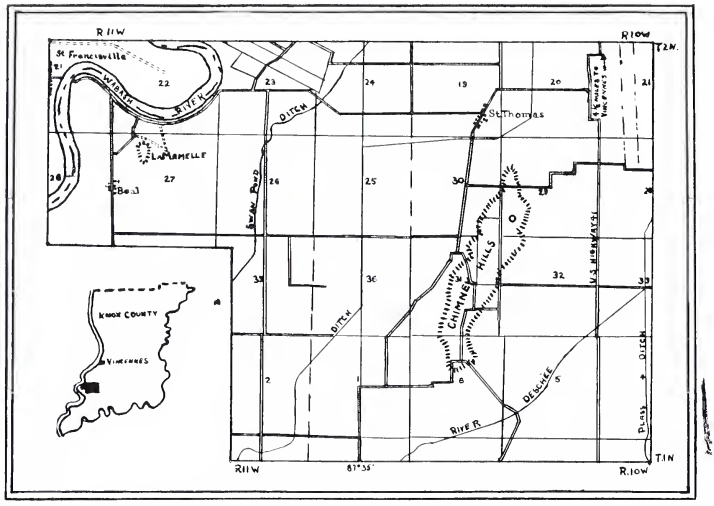


Fig. 1. Sketch map of a part of the lower Wabash valley in southwestern Knox County, Indiana, showing the location of Chimney Hills and La Mamelle.

It is assumed from the evidence produced by well records and exposures that the Wabash formerly flowed in a more restricted valley, far deeper than the present one. This prior valley served as a sluiceway[4] for the melt waters of the Pleistocene glaciers and for the waters from glacial Lake Maumee. In the vicinity of Vincennes it is believed that the eastern wall of this valley was overhanging. It is reported by Cox[5] that a well in Vincennes penetrated several feet of sandstone and then passed into fluvial gravels and sands. The lower Wabash valley is filled with alluvium 100 feet or more above its bedrock floor, and cliffs and hills have been partly or entirely buried. The filling of the valley was attended by expansion over low parts of the adjacent upland. The tops of some of the remnants of the partially buried upland stand above the surrounding valley flat.

[4] The term *sluiceway* will be used throughout this paper and will have the meaning proposed by C. A. Malott and R. R. Shrock, Features of the Wabash Sluiceway of Northern Indiana, Bull. Geol. Soc. Amer., **40**:101, 1929. "It (the Wabash valley-trough) is here designated a *sluiceway* because it is a troughlike runway through which coursed confined glacial waters of great volume."

[5] Cox, E. T., Geological Survey of Indiana, **1873**:324.

Geology. The Wabash valley in southern Indiana is carved in the Upper Pennsylvanian formations. In Knox County and in the adjacent parts of Illinois the following formations outcrop:

5. St. Wendell sandstone .....45 feet
4. Parker formation (undcl., coal, blk. sh., ls.).....20 feet
3. Merom sandstone .....60-100 feet
2. Ditney formation (coal, sh., ss.).....0-10 feet
1. West Franklin formation (ls., sh.).....15 feet

The Merom sandstone is a friable rock, loosely cemented with iron oxide and calcium carbonate, though on exposed surfaces it is often case-hardened. The color where exposed is brown to light yellowish brown. Due to the unevenness of the disconformable base of the Merom, the thickness of this formation is variable, ranging from 60 to 100 feet. In the described locality, the thickness has been shown by well records to be 100 feet or slightly more. The erosional remnants found in this section of the Wabash sluiceway are composed of this sandstone. Occasionally in the higher isolated hills, the Parker suite of coal, shale and limestone is exposed immediately above it.

In a personal communication from Dr. Malott, the writer learned that the top of the Merom had been determined in several points in Illinois adjacent to the described area. Two miles south of Lawrenceville and at St. Francisville the elevation is 425 feet above sea level, and at the foot of the Robeson Hills northeast of Vincennes it is 420 feet. The top of this formation at the Dicksburg Hills in southern Knox County has an altitude of less than 400 feet above sea level and is below drainage level at this point.

Chimney Hills. Chimney Hills are located about seven miles south of Vincennes near the eastern border of the old sluiceway floor, and extend about two and one-half miles from the SW ¼ of NW ¼, sec. 29, T. 2 N., R. 10 W., to near the middle of sec. 6, T. 1 N., R. 10 W. The trend of the major axis of the hills is 18° west of south, which is near the general direction of elongation of the majority of the erosional

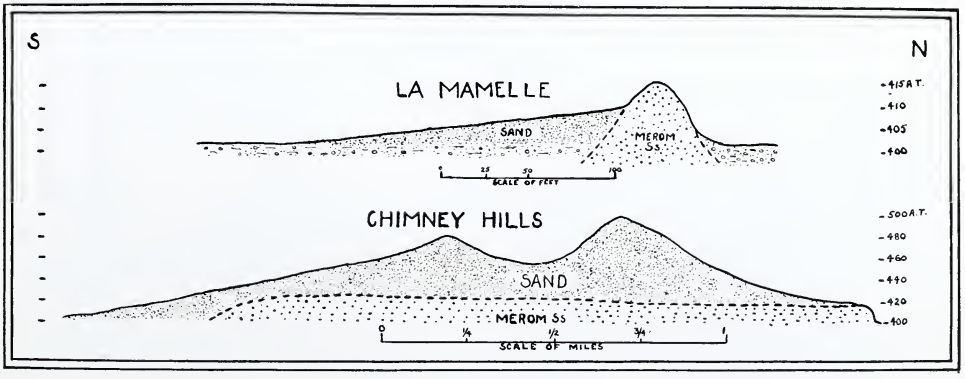


Fig. 2. North-south cross section of La Mamelle and Chimney Hills, showing the relation of the Merom sandstone to the two remnants.

remnants in the district. The hills have an average width of one-half mile, but narrow on the northern and southern ends.

The Merom sandstone underlies the entire isolated mass (Fig. 2) with the exception of the extreme southern end, where the sands have formed a "tail" stretching in a down-valley direction behind the buttress of the stone. At the northernmost end of the hills, the Merom forms a fifteen-foot bluff extending completely around this end. The rock is in place at this outcrop with the exception of several large blocks which have slumped from the sides. The altitude of the top of this exposure is 423 feet above sea level, so that it may be assumed that it is near the top of the Merom sandstone. The rock here is brownish in color on a fresh surface, and the exterior has been exceptionally case-hardened by iron impregnation.

One-eighth mile south of the bluff-head of the Chimney Hills, gravel with erratic pebbles is abundant in a small swale on the surface of the hills. These erratics are composed of gneiss, granite, quartzite, vein quartz, and schist. Farther south the crest of the hills rises to an elevation of 500 feet above sea level, or about 100 feet above the broad valley in which they occur. The southern end is composed of sands of the light brown variety found in the sand dunes which blanket the hills to the east of the sluiceway. The sand resting on the remnant hill is undoubtedly also of eolian origin. Beneath the sand dunes, the Merom formation is exposed in several gullies along the flanks of the ridge near the bottom, but in no place is the Parker formation to be found. It is apparent that the less resistant rocks have been eroded from the top of the hills.

Immediately back of the bluff at the northern end, the same rock is exposed over nearly an acre of the surface of the hills. There is no soil covering here and the rocks are marked in places by shallow scratches or striations. There are several sets of these grooves, inclined to one another at angles from only a few degrees to 90°. The principal scratches trend north-south and east-west, though many of the sets have a northwest-southeast direction. No northeast-southwest markings were noted. At first the writer was inclined to believe that these were glacial striae, carved by the movement of the Illinoian ice sheet over the region, though the angular relations of the sets of scratches were not readily explainable by the differential movement of the ice in the mass. Subsequent burial of the rock surface by till and the removal of the covering by the melt waters that flowed through the valley at a later time were postulated as the agencies which were responsible for the preservation and exposure of these interesting features. But in view of the fact that fluves have been found along the course 55 feet above the floor of the valley, it is not practical to assume that erosion in such a mass of water would not have removed the shallow scratches.

It is well known that blocks of ice containing included rock fragments floated down the Wabash River in the melt waters, since some of these foreign boulders have been found buried in the sands and gravels of the alluvial plain. In view of this fact, an alternative hypothesis for the formation of the markings is the stranding of cakes of floating ice on the rock mass when the valley was flooded with melt waters. If the

boulders in the stranded ice blocks were dragged across the rock, certainly scratches would be formed on the surface of the friable Merom sandstone. The shifts in the current would account for the various orientations which the grooves possess. These grooves may also have an artificial origin, and indeed some of them seem to indicate this, though the majority are too straight and evenly spaced to have been formed in this manner. It is possible that the scratches are due to a combination of the last two agencies mentioned, scratching by artificial means and the dragging of stranded ice blocks across the surface.

On the flood plain along the eastern side near the northern end of the hills, a narrow swamp occupies a small swale about 100 yards long. Immediately adjacent, to the east, a swell rises about ten feet above the general level of the broad alluviated valley floor. It is believed by the author that the swale was formed by the sweep of the current around the bluff at the northern end of the ridge. The swell was formerly a bar, originating from the material which was carried away from the river bed at the side of the former bedrock island.

La Mamelle. La Mamelle is located four miles slightly west of north of the Chimney Hills and about one-half mile northeast of the small village of Beal. It is in the NE ¼ of NW ¼, sec. 27, T. 2 N., R. 11 W. This hill is a cone-shaped erosion remnant composed entirely of Merom sandstone, at about the same horizon as that in the Chimney Hills. The visible part represents the crest of a hill which barely escaped complete burial beneath the alluvium of the broad valley floor (Fig. 3). The top of this isolated hill has an elevation of 423 feet above sea level, and stands fifteen feet above the surface of the flat sluiceway floor at this point. The elevation of the top of the exposure of Merom sandstone at St. Francisville, one mile northwest of La Mamelle, is 425 feet. Since the formation at this point lies nearly on the axis of the Central Interior Coal Basin, and the beds are almost horizontal, it may be assumed that the crest of the hill is at the top of the Merom.

A tail of sand (Fig. 2) extends for 200 feet downvalley from the remnant in a direction 25° west of south. This light brown sand is in contrast to the black alluvium covering the remainder of the area, and was formed as a bar behind the hill when it was a bedrock island in the former waters of the Wabash sluiceway.

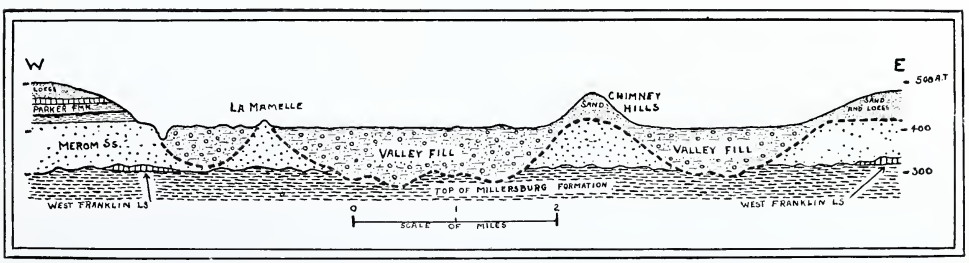


Fig. 3. East-west cross section of the Wabash valley in the vicinity of La Mamelle and Chimney Hills, showing the alluviated valley braids and hills of circumalluviation. The broken line represents the profile of the former valley floor.

CONCLUSION

It is a generally accepted fact that the Wabash River at the beginning of the glacial epoch or soon afterward occupied a valley much deeper than the present one, and that during the ablational period of the Wisconsin ice sheet great quantities of melt waters were discharged down this valley sluiceway. The enormous quantities of detrital materials furnished by the ice to this flooded stream were deposited on the bedrock floor, building it up until the heavily loaded stream was forced to seek additional channels in the pre-existent valleys at the edge of the bordering upland. At the places where the water first spilled over the fluves, the residual material was swept from the rock, and in Illinois a few of these rock floors, cleaned by the current, are still exposed. In the deeper parts of the fluves, alluviation was the dominant process, as was the case in the main channel of the sluiceway.

In many places in northern Indiana, evidences of anastomosing valley troughs are found along the course of the Wabash River. Cumings and Shrock[6] have described the upper Wabash valley as consisting of a number of interlacing parts, all occupied at one time by the great anastomosing river. They have proposed the name *valley braids* to apply to the present streamless or abandoned valley channels. Malott and Shrock[7] have also discussed these features of the Wabash sluiceway as follows: "*Valley braid* is a term proposed for the individual runway of a valley which is in anastomosis, its valley parts passing around features in bas-relief or about upland tracts. The floors of the valley braids may be near the level of the one which carries the present stream or they may be much higher. Valley braids are numerous in some stretches of the Wabash sluiceway. . . . The present river channel chooses its way among them, as it were, and occasionally passes through one with vertical walls strikingly close together. . . . They range in width from narrow rocky floors a few yards across to mighty valleys a mile wide. The wide valley braids are in glacial drift."

In the upper section of the river the valley braids never became exceedingly wide, but in the lower stretches of the sluiceway where the greatest alluviation occurred, these anastomosing streams extended their valleys laterally as the floors were raised by deposition, until the upland masses around which they were braided were reduced to mere fragments standing above the water. As the waters receded, the Wabash apparently occupied any valley of its choosing and the remainder of the valley braids became streamless valleys surrounding bas-relief features. It is for these fragmentary upland masses, surrounded by abandoned valley braids, that the writer proposes the name *valley braid core*, or more simply, *braid core*. This term is used in the same sense as the term *meander core* is used to denote the upland mass around which waters formerly flowed in a meandering valley.

[6] Cumings, E. R., and Shrock, R. R., The Geology of the Silurian Rocks of Northern Indiana, Indiana Dept. Conservation, **1928**:40.

[7] Malott, C. A., and Shrock, R. R., Features of the Wabash Sluiceway of Northern Indiana, Bull. Geol. Soc. Amer., **40**:102, 1929.

GEOLOGIC STRUCTURE OF THE UNIONVILLE GAS FIELD, MONROE COUNTY, INDIANA

RICHARD FREED, Indiana University

Location. The Unionville gas field is located in Benton Township, northeastern Monroe County, about eight miles northeast of Bloomington. It embraces an area of eight or nine square miles, between Unionville Station on the Illinois Central railroad and the village of Old Unionville, three miles east.

History of the Field. The structural conditions in the vicinity of Unionville had been considered to be favorable for the accumulation of gas or oil for several years before drilling operations were commenced. Logan wrote of the possibilities of oil or gas production in the area, in 1922.[1] It was not until October of 1929, however, that the first well was drilled, by the Ohio Oil Company and the Petroleum Exploration Company. This well had an initial production of 900,000 cubic feet of gas. To the present time, fourteen wells have been drilled by the same companies, ten of them being good producers with an average of nearly one million cubic feet of gas per well. Three were dry holes, having been located too far west on the structure, while another was drilled as a deep test to the Trenton formation, which proved unproductive. Drilling is continuing and it is probable that several more successful wells will be drilled.

The gas is obtained from the Devonian limestones of Onondaga age, known to drillers as the "Corniferous lime." The gas horizon is reached at an average of 40 to 50 feet below the top of the formation, and between 750 and 900 feet below the surface, depending upon the altitude of the top of the well.

TOPOGRAPHY

The southwestern portion of the area is a fairly level, upland plain, capped by Harrodsburg limestone, while farther to the north and east, where the limestone is very thin or entirely absent, the streams have cut down into the softer shales and sandstones, forming sharp, narrow ravines which soon develop into broad, flat valleys. This highly dissected region is characteristic of Borden (Knobstone) topography.

A level, narrow ridge extends across the entire district, from Unionville Station in section 18 northeast for two miles, and then directly to the east through Old Unionville and for some distance into Brown County. This is commonly called the "Unionville Ridge" and has an average elevation of nearly 900 feet. It forms the divide between the tributaries of Bean Blossom Creek on the north and of Salt Creek on the south. The main valleys have been cut down to an elevation of between 650 and

[1] Logan, W. N. Handbook of Indiana Geology, Part V, p. 842, 1922.

700 feet. Several lesser ridges lead to the north and to the south from the main divide.

Many of the ravines contain small waterfalls, formed either by a resistant limestone layer in the lower Harrodsburg limestone, or in the upper Borden, by a harder sandstone ledge which is underlain by more easily eroded sandstones or shales. Springs are a common feature along outcrops of the Harrodsburg-Borden contact.

STRATIGRAPHY

The rocks outcropping in the area are of Mississippian age. The highest formation is the Harrodsburg (Warsaw) limestone, which is present on the higher hills or divides but which, over the greater portion of the area, has been removed by erosion. The sandstones and shales of the Borden Group underlie the Harrodsburg limestone, and are the only other rocks which are found in the Unionville Region.

Harrodsburg limestone. The lower 25 to 30 feet of the Harrodsburg has been called the Ramp Creek member of the lower Harrodsburg, by Stockdale.[2] It is characterized by the great numbers of geodes in the basal portion and by highly crinoidal limestone layers, but contains many shaly and sandy horizons and "bastard rock." Practically all of the limestone outcropping in the Unionville region belongs to this lower member, which shows a considerable lithologic variation in different places. For instance, the limestone horizons, highly crinoidal or crystalline at one outcrop may, in a comparatively short distance, change to a very siliceous or shaly rock, almost devoid of fossils. This is especially true of the basal layers, the more massive and persistent horizons appearing higher up in the formation. In the same manner, the basal siliceous geode layer, which also contains a considerable amount of chert toward the top, varies in thickness from only a few inches to a maximum of twelve feet, and in a few localities may be entirely absent, being replaced either by the fossiliferous limestone or by a sandy layer.

Outcrops of the Harrodsburg limestone are found almost entirely across the area from west to east, along the Unionville ridge and on several of the higher divides to the north and south, being cut off near the center of section 10 by the Mt. Carmel Fault. On many of the hills, although no actual outcrops of limestone can be found, a residuum of chert, geodes and small slabs of limestone is present. (See Fig. 1.) This residuum has been left from the decomposition and erosion of the limestone. The approximate altitude of the base of the Harrodsburg can be determined with a fair degree of accuracy, by noting the thickness or amount of the residue and the amount of decomposition which it has undergone.

Borden Group. The total thickness of the Borden, as obtained from the records of the gas wells, averages 665 feet, but only the upper formations are exposed.

The highest and most important Borden formation in the Unionville region is the Edwardsville formation. (See Fig. 2.) This was formerly

[2] Stockdale, P. B. The Borden (Knobstone) Rocks of Southern Indiana. Ind. State Dept. Cons., Publication No. 98, p. 240, 1931.

Fig. 1. Residuum of chert and geodes left from the decomposition of the basal Harrodsburg limestone.

known as the "Riverside sandstone," but was renamed "Edwardsville" by Stockdale.[3] The upper portion is usually a succession of fine-grained sandstone and siltstone beds, with shaly partings. Some of the sandstones form prominently resisting ledges. One of these called by Stockdale the *Mt. Ebel sandstone member*, proved to be of considerable value in determining structural conditions where outcrops of the Harrodsburg were absent. It is of a dark yellow color, often mottled by iron streaks and ranges from one to five feet in thickness. It occurs between five and

Fig. 2. Contact of the Harrodsburg and Borden at the west end of the Illinois Central railroad tunnel. The limestone is underlain by the basal chert and geode layer. The top of the Borden (Edwardsville formation) is at the level of the top of the concrete.

[3] Stockdale, P. B. The Borden (Knobstone) Rocks of Southern Indiana. Ind. State Dept. Cons., Publication No. 98, p. 220, 1931.

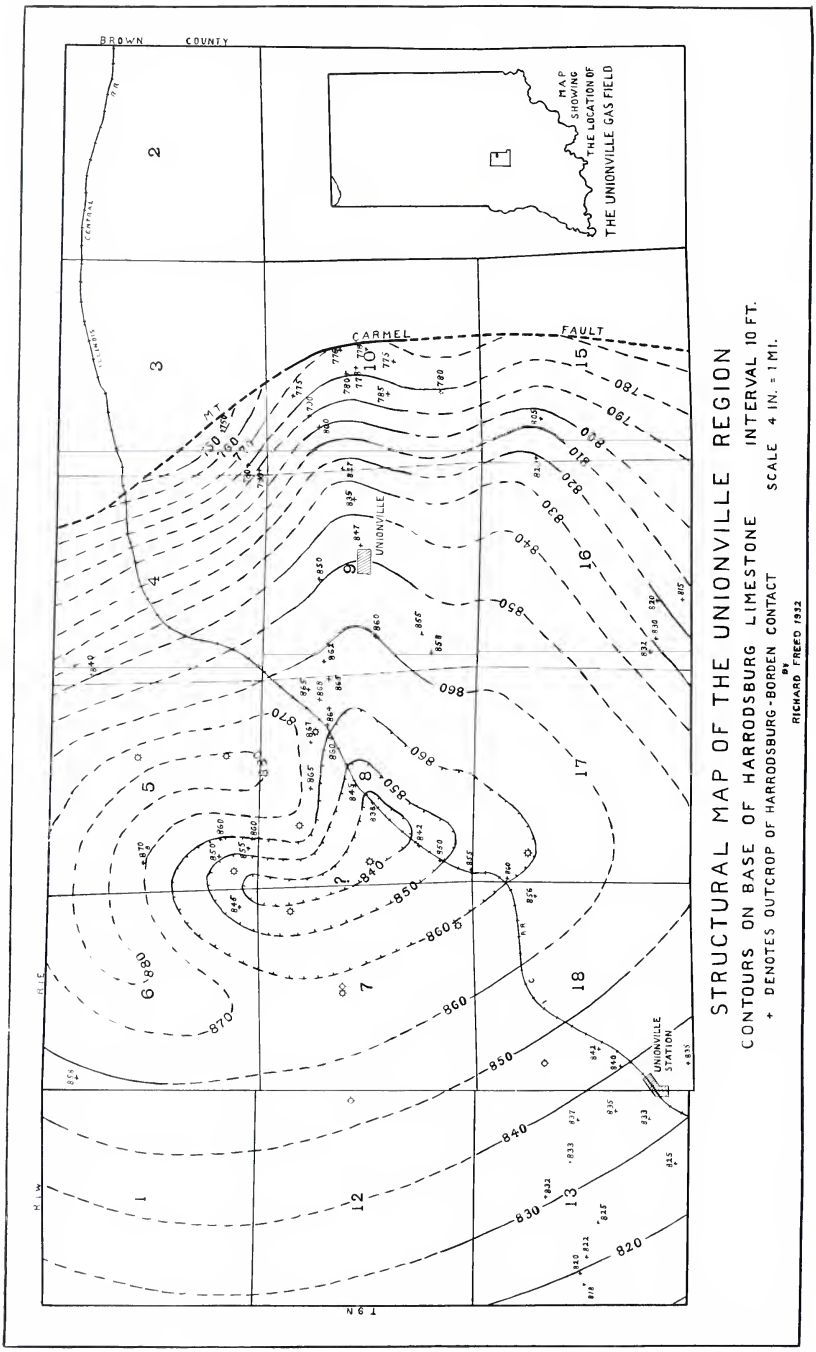

STRUCTURAL MAP OF THE UNIONVILLE REGION
CONTOURS ON BASE OF HARRODSBURG LIMESTONE
INTERVAL 10 FT.
+ DENOTES OUTCROP OF HARRODSBURG-BORDEN CONTACT
SCALE 4 IN. = 1 MI.
RICHARD T. FREED 1932
MAP SHOWING THE LOCATION OF THE UNIONVILLE GAS FIELD
BROWN COUNTY
CARMEL
FAULT
UNIONVILLE
UNIONVILLE STATION
N 6 T
R 1 E
R 1 W

Fig. 3

ten feet below the base of the Harrodsburg limestone and is characterized by the presence of large forms of *Derbya keokuk, Syringothyris textus,* several species of *Productus* and *Eumetria.* Below the Mt. Ebel sandstone is found a succession of siltstones, argillaceous sandstones of gray to drab color. These abound in worm markings, but other fossils are rare.

The total thickness of the Edwardsville rocks in the Unionville area averages around 180 feet.

Structural Conditions

Mt. Carmel Fault. The Mt. Carmel Fault is the feature which has produced the structural conditions as they now exist in the area. (See Fig. 3.) It has been traced from Washington County to southern Morgan County, a distance of about fifty miles. Newsom called it the "Unionville Fault" in 1903, from its exposures one mile east of the village of Old Unionville.[4] In the same year Ashley named it the Mt. Carmel Fault, from Mt. Carmel Church in northwestern Washington County. The latter name is the one which has come into common use.[5]

The fault can be traced for only a short distance in the Unionville region. This is in section 10, one mile east of Old Unionville, both north and south of State Highway 45. About 150 yards west of where the road makes a turn to the north, a small ravine leads to the north. This ravine is in Harrodsburg limestone. At the place where the ravine joins another from the east, the base of the limestone lies at an altitude of 780 feet. Limestone occurs in the north bank of the second ravine for a distance of about thirty feet, being suddenly cut off by a weathered, fractured rift zone. This fault zone is followed by fairly massive ledges of sandstone of the Edwardsville formation, which is present all the way up the ravine to the top of the hill, 200 yards to the east, where the elevation is 890 feet. The width of the rift zone is twenty-five feet, and the trend of the fault at this place is nearly due north and south.

One-half mile north of where the fault crosses State Road 45 in section 10, the fault line makes a turn toward the northwest at an angle of between 30 and 35 degrees. It then enters the valley of Shuffle Creek, and cannot be located again for a distance of two miles. In the northwest quarter of section 4, evidence of displacement can be seen in a small ravine a short distance south of the Shuffle Creek road. Further proof that the fault is nearby is found in the presence of low-lying beds of limestone one-half mile to the northwest, along the road descending into Bean Blossom valley. The fault has been located again several miles north of Bean Blossom Creek, in Marion Township.[6]

South of the State Road in section 10, the fault has been followed for one-fourth mile, where it appears to bend slightly east of south and enters the valley of Brummets Creek. It was not traced farther in the area covered in this paper, but it can be seen in numerous localities farther south in Monroe and Lawrence Counties.

[4] Newsom, J. F. Geologic Section Across Southern Indiana. 26th Indiana Report, p. 274, 1903.

[5] Ashley, G. H. Geology of the Lower Carboniferous Area of Southern Indiana. 27th Indiana Report, p. 91, 1903.

[6] Freed, R. and Rogers, R. A Fault Along Bryants Creek, Northern Monroe County. Proc. Ind. Acad. Sci., Vol. 41, 1931 (1932).

The amount of the throw has not been accurately determined in this region, but it probably averages around 150 feet. The ridge immediately east of the fault in section 10 has an altitude of nearly 900 feet and is composed entirely of Borden rocks. The base of the Harrodsburg at the fault lies at 980 feet, giving a throw of at least 120 feet. Assuming a normal rise of 30 feet per mile from Unionville Station to the fault line in section 10, the base of the limestone, before faulting, would have been at 925 feet, 145 feet above its present location. In the southwest quarter of section 3, the throw is at least 30 feet more than it is in section 10.

The elongated anticline on the west or downthrow side of the fault was named the Dennison Anticline by Esarey in 1924.[7] It is present throughout the extent of the fault, from northwest Washington County to southern Morgan County. The crest of the anticline is undulating, with numerous domes and depressions. The dome in the Unionville region is probably the largest one of the entire anticline.

Structure of the Dome. The dome of the Unionville region is unusual in that a syncline is present nearly where highest portion would be expected to be found. This synclinal area will be described later.

In the western and southwestern parts of the area, in sections 12 and 13, the dip is normal, 30 to 35 feet per mile toward the west-southwest, the lowest contour being the 810 foot level. In the center of section 7 and the northwest quarter of section 18, the 860 foot elevation is reached. The rocks lie practically level for more than one-half mile before dipping into the synclinical areas in section 8 and the southern part of section 5. In the northern portion of section 17 and in the eastern part of section 8, elevations of 860 to 865 feet are found. The highest portion of the structure appears to be in a narrow strip which extends from the northeastern quarter of section 8 through the center of section 5 and into the east half of section 6. The limestone in this area is practically all gone, but elevations of the Mt. Ebel sandstone in several places show that the structure reaches at least 880 feet.

The reversal, or dip toward the fault, begins in the western parts of sections 4, 9 and 16. The dip is at first very little, but as the fault is approached it becomes greater, as much as fifty feet in less than one-half mile. The total amount of reversal from the northeast quarter of section 8 to the fault in section 10 is approximately 100 feet, while in section 3 it is at least 30 feet more. It may be still more, farther south, in section 15.

Determination of the actual amount of reversal to the north and south is difficult because of the almost complete absence of the Harrodsburg limestone. In Marion Township, north of the area mapped, some of the residuum from the decomposition of the limestone can be found. Along a north-south road between sections 32 and 33, a considerable amount of chert and geodes, together with some limestone, makes it quite certain that the Harrodsburg-Borden contact lies between 850 and 860 feet. This is about one mile north of the 880 contour in the northern part of section 5, and it shows that there is an appreciable dip toward

[7] Esarey, R. E. Notes on the Relation of the Mt. Carmel and Heltonville Faults to the Dennison Anticline. Proc. Ind. Acad. Sci., Vol. 34, p. 138, 1924 (1925).

the north. It is probable that this dip continues toward the north and northwest and may reach to well below 850 feet in the vicinity of Bean Blossom Creek, two miles north.

On the south, the 850 and probably the 840 foot contours are closed, but it is doubtful whether the closure is much greater in this locality. There is some evidence that the structure again rises south of section 17, perhaps to form a second, smaller anticline, but the actual conditions will not be known until further work has been done.

The Syncline. The sag or syncline in section 8 is most admirably displayed in the cuts along the Illinois Central railroad, for a distance of three-fourths of a mile southwest of the railroad tunnel. The strong dips of the rocks can easily be seen, and the Harrodsburg-Borden contact is present in most of the cuts, making an accurate study of the syncline quite simple. (See Fig. 4.)

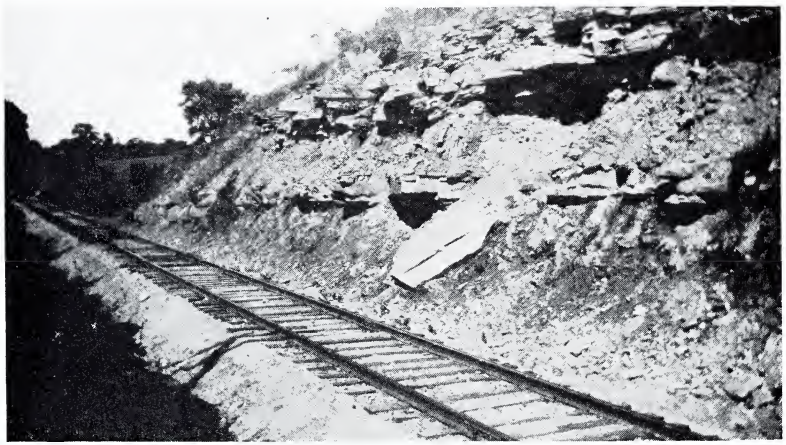


Fig. 4. Rocks of the lower Harrodsburg dipping toward the bottom of the syncline in section 8, seventeen hundred feet southwest of the Illinois Central tunnel.

At the southwest corner of section 8, where the reversal from the normal dip begins, the elevation of the base of the Harrodsburg is nearly 870 feet. To the northeast, through several cuts, the rocks dip quite strongly until at a point 1,500 feet southwest of the tunnel the bottom of the sag is reached. A ravine and railroad fill have destroyed the evidence at this place, but the elevation is probably between 830 and 835 feet. From here to the tunnel the structure again rises, reaching 860 feet at the west end of the tunnel and several feet higher one-fourth of a mile to the east.

There is a rapid rise toward the south from the bottom of the syncline. In several ravines heading south of the road in the south half of section 8 Borden rocks are present, the Mt. Ebel sandstone being found at 860 feet. Adding ten feet to obtain the approximate altitude of the contact gives 870 feet, which is nearly 40 feet higher than the base of the sag one-fourth mile north.

To the north and northeast there is a similar rise to an even higher level, reaching 870 or 880 feet within a distance of one-half mile.

Northwest of the syncline the land becomes so low that determinations of structural conditions based on the Harrodsburg or upper Borden are impossible because of their almost complete absence.

A similar sag or syncline occurs in the southwest quarter of section 5, three-fourths of a mile north and slightly west of the first one. Here again the rocks appear to rise on all sides, although toward the south the fact cannot be established with certainty.

The base of the Harrodsburg limestone is found to have an altitude of about 845 feet in an abandoned quarry in the center of the southwest quarter of section 5. A short distance west the elevation is slightly less than 840 feet. Still farther west it again reaches 845 feet, and in another quarter of a mile the limestone disappears but the Mt. Ebel sandstone is found at 860 feet, making approximately 870 feet for the contact. Similar conditions exist both to the north and to the east, with Borden rocks lying at elevations of between 870 and 880 feet.

There is a possibility that both of the low areas above described may be connected and they have been thus drawn on the map. In one direction from each syncline there is a lack of evidence to prove that they are separate basins. The first might continue toward the northwest, while the second could have an outlet to the south, thus forming a single elongated syncline. If this is the case, it must then be rather crescent-shaped, because almost directly between the two visible low areas, Borden sandstones are found at an elevation of at least 870 feet.

Conclusions Regarding Structural Conditions. As has been stated before, the structural conditions present in the Unionville region are very unusual. The presence of a syncline or of two separate ones in the center of a fairly regular elongated dome or anticline difficult to explain.

It might be expected that minor block faulting could have accounted for the low areas. Their nature, however, and the conditions immediately surrounding them on all sides makes it almost impossible to ascribe them to such a cause. Careful study, moreover, has failed to reveal any evidence of block faulting.

It seems possible that the sags may have been produced in connection with the change of direction of the fault in section 10. But the manner in which the forces acted to produce a collapse so near to the top of the structure cannot be explained by the writer.

It is to be expected that the syncline carries down into the gas-bearing horizon, but positive proof cannot be obtained until further drilling has been done. Assuming that it is present in the Devonian limestones, it is doubtful whether its size is sufficient to produce any noticeable effect upon the amount of gas present. At least one of the wells, in section 5, is located near the lowest portion of the syncline, and good production was obtained from it.

GEOLOGICAL AND STRUCTURAL CONDITIONS IN THE UNION OIL AND GAS FIELD

William N. Logan, Indiana University

Location. The above mentioned gas and oil field is located in section 31 in Pike County and in sections 1, 6, and 36 in towns 1 north and in 1 south in range 9 west and in 10 west in Gibson County, Indiana.

Stratigraphic Conditions of the Field

The formations which are represented in the area include formations ranging in age from the Pleistocene to the Mississippian.

Pleistocene and Post-Pleistocene Formations. The rock materials which have been assigned to these divisions by the writer consist of clays, sands and gravels. The thickness of such deposits in the area varies from a few feet to as much as one hundred feet.

Pennsylvanian Formations. The Pennsylvanian formations underlie the Pleistocene formations. They consist of clays, shales, sandstones, limestones and beds of coal. The total thickness of the Pennsylvanian group in the Union field is as much as 1,000 feet.

The Mansfield sandstone which forms the basal member of the Pennsylvanian group in the area lies uncomfortably upon the eroded surface of the rocks of Mississippian age. In thickness the Mansfield varies from 150 to 250 feet within the Union field. The Mansfield sandstone is of coarser texture, usually, and may be distinguished from the finer textured sandstones of the Chester divisions which lie below it.

The Mansfield sandstone in many parts of Indiana contains one or more beds of coal but in the Union area no beds of coal were recorded in the logs of the wells drilled.

The Brazil group of formations which lies above the Mansfield contains in many parts of the Indiana coal-bearing area the Lower Block, Upper Block, Minshall and Number II coal beds but in the Union area no coal beds were recorded by the drillers for this group of formations.

The Staunton group of formations usually contains coals which are indicated as coals Numbers III, IIIa, and IV. Coals III and IIIa are often thin and in many places in Indiana are not present but Coal IV is usually present. None of these coals were recorded by the drillers in the Union area.

The Petersburg group, which is apparently the most important group in the Union area, contains coal beds Numbers V, VI and VII. These three beds have a total thickness of twenty-one feet. These coals are included in the Allegheny division of the Pennsylvanian system.

The interval between Coal VII and Coal VI in the Union area is 117 feet. The interval between Coal VI and Coal V is 140 feet which

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

is greater interval than that which exists between these coals in the northern part of Indiana.

Coal V has thickness of ten feet and lies 320 feet below the surface in the Union area. Coal VI has a thickness of five feet and lies 320 feet below the surface. Coal VII has a thickness of six feet and lies 197 feet below the surface in the Union area.

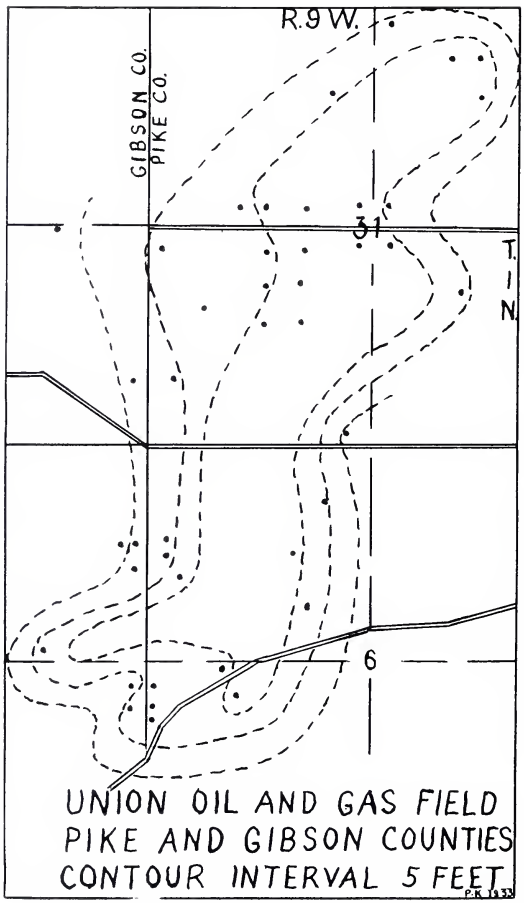


Fig. 1.

STRATIGRAPHIC COLUMN IN THE UNION AREA

Pleistocene and Post-Pleistocene Formations

Soil	1 foot
Clay, yellow, soft	19 feet
Sandy clay, hard (hardpan)	8 feet

Pennsylvanian Formations

Shale, light, soft	20 feet
Sandstone, light, broken	12 feet
Shale, dark, soft	55 feet

Sandstone, light, soft	13 feet
Shale, dark, soft	7 feet
Shale, light, soft	10 feet
Sandstone, light, hard	15 feet
Shale, dark, soft	37 feet
Coal	6 feet
Shale, dark, soft	8 feet
Shale, light, soft	19 feet
Shale, sandy, light, soft	45 feet
Sandstone, gray, hard	15 feet
Shale, dark, soft	18 feet
Limestone, brown, hard	6 feet
Shale, dark, soft	6 feet
Coal	5 feet
Sandstone	10 feet
Shale	20 feet
Limestone, hard, white	5 feet
Shale	25 feet
Limestone, white, hard	6 feet
Shale, light, soft	44 feet
Shale, brown, soft	15 feet
Shale, dark, soft	15 feet
Coal	10 feet
Shale, dark soft	10 feet
Limestone, light, medium sandy	10 feet
Shale, light, soft	20 feet
Limestone, light, hard	3 feet
Shale, dark, soft	52 feet
Limestone, gray, hard	3 feet
Shale, light, soft	7 feet
Limestone, medium, soft	5 feet
Shale, light, soft	20 feet
Clay, white, soft	5 feet
Shale, dark, soft	60 feet
Shale, light, soft	80 feet
Sandstone, gray, hard	10 feet
Shale, light, soft	35 feet
Sandstone, medium soft, light	55 feet
Shale, light	5 feet
Sandstone (water)	35 feet
Shale, light, soft	20 feet
Sandstone, light	20 feet
Sandstone, dark	90 feet
Sandstone, white	20 feet
Shale	5 feet

The Chester Formations (Mississippian)

The Chester formations rest beneath the strata of Pennsylvanian age in the Union area. The strata include a series of limestones, shales, and sandstones as follows:

Shale, light, soft	5 feet
Limestone	5 feet
Shale	10 feet
Sandstone, hard at bottom	63 feet
Shale, dark	22 feet
Limestone, gray, hard	12 feet
Shale, light	18 feet
Limestone	5 feet
Shale	5 feet
Limestone, sandy	5 feet
Shale, light	15 feet
Red rock	3 feet
Shale, light	7 feet
Sandstone, gray	23 feet
Shale, dark	13 feet
Limestone	14 feet
Shale	15 feet
Sandstone	15 feet
Shale	6 feet
Sand and oil	12 feet
Total depth	1,323 feet

STRUCTURAL CONDITIONS IN THE UNION FIELD

In order to determine the structural conditions in the Union field a thin brown limestone was used as a key horizon. This limestone was easily recognized in the well cuttings and since the limestone did not vary greatly in thickness throughout the field either the top or the bottom of the limestone could be used as a datum plane. The limestone is probably one in the Golconda formation of the Chester series.

The structural conditions may be due to the compaction of soft sediments or to folding of the rocks. In order to determine definitely the type of structural conditions in the area it will be necessary to drill a number of wells along the axis of the anticline as it is now outlined. The structural conditions may exist as they have been outlined on the structural map or they may consist of a series of small anticlines and synclines occupying the axis of the general anticline. Future drilling will determine definitely the structural conditions of the axis of the anticline as outlined on the structural map.

Members of the field party were: James Organ, Robert Grosjean, George Whitlatch, and Joseph Holm. Mr. Paul Kerr assisted in the preparation of the structural map.

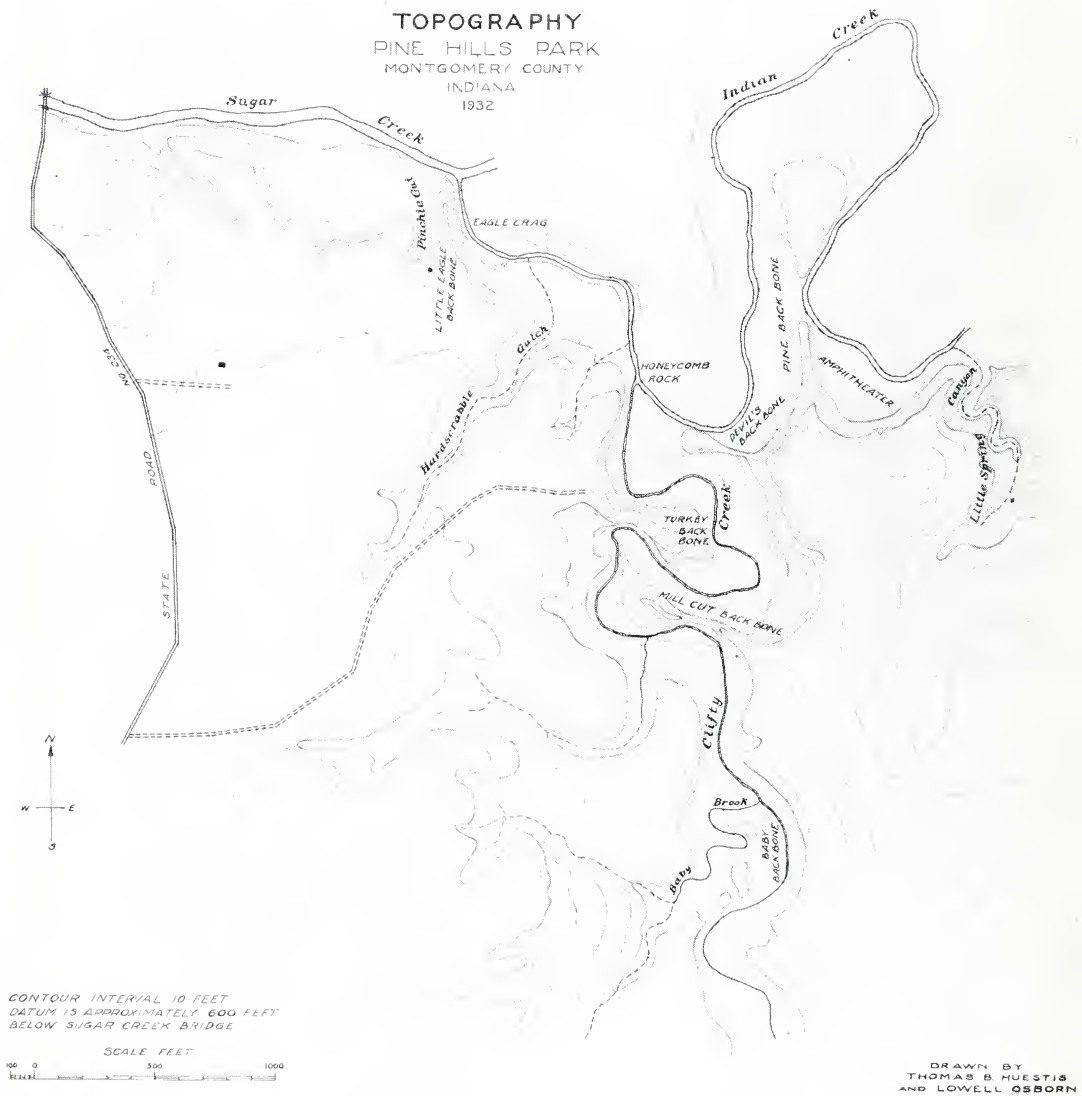

TOPOGRAPHY
PINE HILLS PARK
MONTGOMERY COUNTY
INDIANA
1932
Sugar Creek
Indian Creek
Pinhole Cut
EAGLE CRAG
LITTLE EAGLE BACK BONE
Gulch
HONEYCOMB ROCK
PINE BACK BONE
AMPHITHEATER
Canyon
Little Spruce
DEVIL'S BACK BONE
Horseradish
TURKEY BACK BONE
Creek
MILL CUT BACK BONE
Cliffy
Brook
BABY BACK BONE
Baby
STATE ROAD 234
N
W
E
S
CONTOUR INTERVAL 10 FEET
DATUM IS APPROXIMATELY 600 FEET
BELOW SUGAR CREEK BRIDGE
SCALE FEET
500 0 500 1000
DRAWN BY
THOMAS B. HUESTIS
AND LOWELL OSBORN

Fig. 1

THE PHYSIOGRAPHIC FEATURES OF PINE HILLS NATURE STUDY PARK, MONTGOMERY COUNTY, INDIANA

Ernest Rice Smith, DePauw University

The incised meanders and other features of natural interest in Pine Hills Park, Montgomery County, Indiana, have aroused such interest among, not only physiographers, but also lovers of nature, that a careful map and study of the park have seemed thoroughly worthwhile. A task of this sort could not have been completed without the hearty cooperation of many individuals. A list of those who have helped is appended to this paper and appreciation for their interest and effort is sincerely expressed.

Location. Pine Hills Nature Study Park, at times called Devil's Backbone, after one of its interesting features, is located in sections 1, 2, 11 and 12, Brown Township, Montgomery County, Indiana. It is about fifteen miles from Crawfordsville, the county seat, and five miles from Waveland, the nearest railroad town and post-office. Pine Hills Park, as a whole, lies on both sides of Sugar Creek and of Indiana State Road 234, where that road crosses Sugar Creek on a fine two-span covered bridge. Although all parts of the park contain points of interest—the great deposits of calcareous tufa with their weird shapes at the base of the Mansfield sandstone, the etched cliffs opposite Bluff Mills, waterfalls, glens, etc.—the immediate subject of this paper is the region of backbones and incised meanders east of road 234 and south of Sugar Creek. Wherever Pine Hills Park is mentioned it may be inferred that this section of the park is indicated.

Drainage. The park is entirely within the drainage basin of Sugar Creek, sometimes called Rock River, an important tributary of the Wabash River. The park drainage is: (a) by steep, short gullies which tumble down into Sugar Creek, e. g., the gullies behind Hemlock Lodge; (b) by Indian Creek (one of the seventeen Indian Creeks in Indiana) and its gullies such as Pinchie Gut and Hardscrabble Gulch; and (c) by a tributary of Indian Creek called Clifty Creek, with its own tributaries such as Camp Brook and Baby Brook. (Fig. 1.)

Topography. Physiographically, Pine Hills Park lies in that part of Indiana above the glacial boundary, called by Fenneman the Till Plains Section of the Central Lowland Province. In the nomenclature in current use in the state, it is in the Tipton Till Plain, but due to the marked entrenchment through the till mantle down into the bed-rock, as at the Shades and Turkey Run, the immediate relief takes on the characteristics of the Crawford or Norman Uplands of southern Indiana. (Fig. 2.) In

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

Turkey Run State Park, there outcrops the Mansfield sandstone, the basal member of the Pennsylvanian System in Indiana, which formation gives character to the Crawford Upland farther south in Indiana. In the Shades, the steeper cliffs are due to the Mansfield and, in the lower portions, the more gradual slopes are due to the Borden, the underlying rock in the Norman Upland. At Pine Hills only the Borden is found.

The main structural feature of the bedrocks in Indiana, which determines the distribution of formations, is the western limb of the Cincinnati Arch which trends off in the general direction of Chicago. South of the glacial boundary this gives the rocks a general W-S-W dip of from 20 to 40 ft. per mile. This regional dip determines the trend of the physiographic provinces in a N-N-W direction.

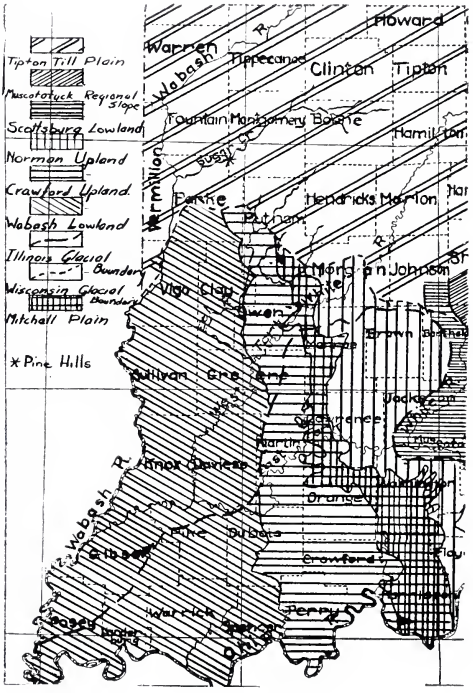


Fig. 2.

From Putnam County south, between the Norman Upland on the east and the Crawford Upland on the west, is the Mitchell Plain, with a more or less typical karst topography due to the development of three limestones: the Harrodsburg, Salem and Mitchell. Because of the thinning down of the limestones toward the north, the Mitchell Plain gradually narrows and finally disappears altogether. The two uplands would fuse into one with the characteristics of the Norman on the east and the Crawford on the west were it not for the work of the great ice sheet. Chiefly because of deposition by the Wisconsin glacier, the region north of Greencastle is not a highly dissected upland, but a slightly rolling till

plain. There are sags and swells characteristic of the general monotony and only where recessional moraines exert their influence do we have a more hummocky topography with knobs, kames and kettles. Where Sugar Creek has cut across the Borden-Mansfield belt, it makes another exception to the montonous surface, incising a relief comparable to that of any place in the Norman or Crawford Upland. This erosion gives the remarkably fine look-out points of Turkey Run, the Shades and Pine Hills Park. In Pine Hills Park, an automobile may be driven to the very edge of an almost sheer cliff, 120 feet high looking out over Clifty and Indian creeks.

Stratigraphy. In the portion of Pine Hills under discussion, the only bedrocks exposed belong to the Borden formation. Stockdale has recently expressed the opinion that they lie in the upper part of the Carwood subdivision of the Borden. The section exposed is about as follows:

3. Heavy-bedded shaly sandstone or siltstone..... 8–10 ft.+
2. Interbedded crinoidal, crystalline biostromes and shaly sandstone ..... 5– 6 ft.
1. Shaly sandstone showing limonite concretions, irregularly cemented; almost no fossils; heavier-bedded, less argillaceous above..... 70 ft.+

Zone 1. The lowest portion of the section as shown throughout the park is somewhat over 70 feet thick. In large part, it is a shaly sandstone. It contains so much argillaceous material that weathering takes place due to frost action, parallel to the surface, the rock spalling off in great flakes up to several square feet in area and two or more inches in thickness. (Fig. 3.)

Another characteristic of Zone 1 in the Carwood is closely connected with the argillaceous content of the lower portion as contrasted with the more arenaceous, heavier-bedded upper part. Wherever talus is removed

Fig. 3.

as rapidly as it accumulates, markedly undercut cliffs are found. Figures 3 and 4 show this characteristic on the south side of Turkey Backbone and the north side of Devil's Backbone. Frequently these excavated areas are coated in spots with Epsomite.

A third outstandingly interesting characteristic of Zone 1 is the irregular cementation which in places results in marked differential weathering: the Honeycomb Rocks at the junction of Clifty and Indian

Fig. 4.

Fig. 5.

Creeks (Figs. 5 and 6), the undercut on the south side of Devil's Backbone and the etched surface on the upper part of Eagle Crag.

The more siliceous upper layers in Zone 1, in addition to supporting the overhanging cliffs, also form the Devil's Backbone (Fig. 7) and are present in the upper portion of Turkey, Mill-Cut and Pine Backbones.

Fig. 6.

Zone 2. The most interesting strata in Zone 2 are the highly fossiliferous, usually crystalline coquinas interbedded in the sandstones (biostromes of Cumings[1]). They are widespread throughout the park and are the springmakers in the park. Such springs are found where the path crosses Hardscrabble Gulch, on Camp Brook, on Spring Cliff and

Fig. 7.

[1] Cumings: Bull. G. S. A., Vol. 43, p. 331, 1932.

up Little Spring Canyon. All the water is highly charged with calcium bicarbonate so that in the neighborhood of seeps and springs there are deposits of calcareous tufa, nowhere on as great a scale as at the base of the Mansfield. Where the water seeps out through deposits of glacial gravel, as on the east end of Devil's Backbone and on the east side of Clifty Creek above Baby Backbone, the gravel is cemented into a fairly resistant conglomerate or pudding-stone.

The fauna of Zone 2 does not seem large. The best fossils have been found on Mill-Cut Backbone. The biostromes consist largely of crinoid fragments, but some very nice heads, a few Spirifers and fairly common Platyceras have been found there. Up Baby Brook at this horizon was found a slab covered with good-sized productids. In the weathered rock in the knoll on the west end of Devil's Backbone, in addition to the crinoid fragments, are many fenestellids. Where the path crosses Hardscrabble Gulch, the biostromes are made up largely of brachiopods.

Zone 3 outcrops in only a few places in the park and is not markedly different from Zone 1. It outcrops in the Shades in Hemlock and Bridal-Veil Falls. It seems to be non-fossiliferous.

The Backbones. These, the major points of interest in the park, may be located on the contour map of the park (Fig. 1). Without exaggeration, they may be considered as the most remarkable examples of incised meanders in the eastern United States. In fact, although they are exceeded in magnitude by such features in the Rockies, none exceeds them in perfection and in interest. In order of length, they are Pine, Turkey, Mill-Cut, Devil's, Baby and Little Eagle. All except Little Eagle are meander spurs either of one stream on itself or of two streams meandering together. A brief description of the backbones, beginning with the longest, will emphasize their salient points.

Pine Backbone is made by Indian Creek returning on itself after a path of some 3,000 feet. The main backbone is about 200 feet long, narrow at the crest, standing 25 to 70 feet above the flat on either side and with a minimum width of 90 feet at the base. It expands to a considerable width at the far end and rises to a knoll called Bald Mountain, over 80 feet above Indian Creek. The far end of Bald Mountain has a typical slip-slope with two flats which probably indicate temporary halts in the down-cutting process. At the present time, the stream does not swing together nearer than 220 feet. The present meander belt at that point, then, is much narrower than at the time in the past when it would seem to have been a matter of but a few years before Pine Backbone would have been cut through. It was at this time that the amphitheater east of the foot of the backbone was developed. It covers more than five acres and nowhere has a relief of even five feet.

There is one other interesting feature of the Pine Backbone. At the north end of the sag, the crest is bifid, with a trough through the center. Indian Creek seems to have maintained a consistent channel close to the backbone on the east side, so that marked under-cutting took place. At some time in the past, a considerable undercut block slumped off carrying down the higher part of the backbone at that point. This leaves a double crest of nearly equal height. The undercutting continues for some dis-

tance around the side of the amphitheater and at one point the growth of evergreens is so heavy, the depth of the undercut is so great, and the exposure in such a direction, that rain never reaches the back of the undercut. In fact, the whole backbone and the far sweep of the meander are so clothed with evergreens, hemlock and white pine, as to make it impossible to take a picture at any time of the year.

Turkey Backbone, the first one usually seen by tourist and physiographer alike, is made by Clifty Creek meandering on itself. The main crest is merely a very narrow footpath about 230 feet long and about 110 feet above the stream. At the base, it is about 140 feet through from stream to stream, Clifty Creek working actively on both sides. On the south side (Fig. 3) there is a remarkable undercut while the north side is a very steep slope. The head end of Turkey Backbone is a broad meander curve with a typical slip-slope and, like Pine Backbone, with two evergreen-clad flats perched above the present stream level.

Fig. 8.

Mill-Cut Backbone (Fig. 8) is of interest, not only for its scenic and physiographic features, but also for the work of man, the Mill-Cut. In the late fifties a trough about 36 feet deep and some 10 feet wide was excavated at the narrowest part of the backbone. Clifty Creek above the backbone and just below this cut was dammed up and the water led through to operate a small woolen mill on the 32-foot drop thus gained. This interesting utilization of the topography will be at once compared to that at Tunnel Mills near North Vernon, Indiana. Although there was year-round water from the spring-fed creek and the head was good, the volume of water was insufficient and the mill was soon moved to the site of Bluff Mills where road 234 crosses Sugar Creek.

The backbone varies between 70 and 40 feet in height, is 5 or 6 feet wide at the crest, about 200 feet long and 160 feet through at the

base. The south side is nearly vertical, the north side steep with a narrow flat at the bottom. There are the same two flats above the present stream level around the end of the meander spur.

Devil's Backbone, for which the park was originally named, was made by Clifty and Indian Creeks when they were meandering much closer than now. In fact, at one time, they were within two feet of piercing the meander spur. Had this taken place, Clifty would have flowed into Indian Creek through a fine natural bridge and the lower course of the present Clifty Creek would have been abandoned. This abandoned course would have included the north side of Turkey Backbone and the cliff down to Honeycomb Rock. As shown in Fig. 1, there is no immediate prospect of this occurrence as both streams are now flowing well away from the Devil's Backbone.

The backbone is about 125 feet long, 70 feet above Indian Creek and 65 feet above Clifty Creek. It has a minimum width at the top of 7 feet. Overlying dirt and weathered rock have probably been cleared off, but this must have been done before the year 1870, as that date is carved on the backbone. Figure 7 shows the backbone with Indian Creek on the right.

Baby Backbone was formed by Baby Brook and Clifty Creek meandering toward each other after Baby Brook had taken an abnormally long route into Clifty Creek. Were it not for the presence of the other backbones, this neat little backbone some 10 to 25 feet high and 150 feet long would arouse much more interest.

Little-Eagle Backbone is a markedly narrow divide just west of Eagle Crag, between Pinchie Gut and Indian Creek. Through the passage of time Indian Creek has cut farther and farther west narrowing this divide. Otherwise, it would have been a perfectly normal divide between a narrow gully and a small creek. Indian Creek formerly flowed into Sugar Creek just below Hemlock Lodge. Probably with the aid of Sugar Creek it later made a cut-off about 400 feet above its former outlet, forcing Pinchie Gut into a slightly abnormal path into the present Indian Creek.

The Origin of the Backbones. The problem of the origin of the backbones resolves itself into two parts—the marked incision or entrenchment in a region with no other evidences of regional uplift and the development of a meandering course in such a youthful topography.

The cause of the entrenchment of the tributaries of Sugar Creek can be ascribed unquestionably to the great rapidity of the downward cutting processes by the main stream, thus continually, or almost continually, keeping the tributaries youthful. Where this down-cutting was temporarily halted, a shelf would be developed, not only in the main stream valley, but also in the tributaries. Such terraces have been noted in Clifty and Indian Creeks and may be seen in the main Sugar Creek valley from the Lookout Point in the Shades.

The Meanders. Normally streams develop meanders such as these only in a relatively mature topography. Yet this region, far from

being mature, bears all the evidences of youth, the but little eroded Tipton Till Plain. After discarding two other theories the following theory is considered to link up all known evidence as to the cause of the remarkable meander pattern. The following factors must be taken into account: The limitation of incised meanders to the Borden formation whether in the main Sugar Creek Valley as at the Shades, or in its tributaries as at Pine Hills Park; the tendency of the Borden to undercut due to spalling off in freezing weather thus furnishing an abundance of tools, not only for the downward cutting process, but also for swinging wider and wider on curves. This would provide the extensive undercut cliffs rather than the more normal meander scars and the well-developed slip-slopes. A meander pattern would not develop in Turkey

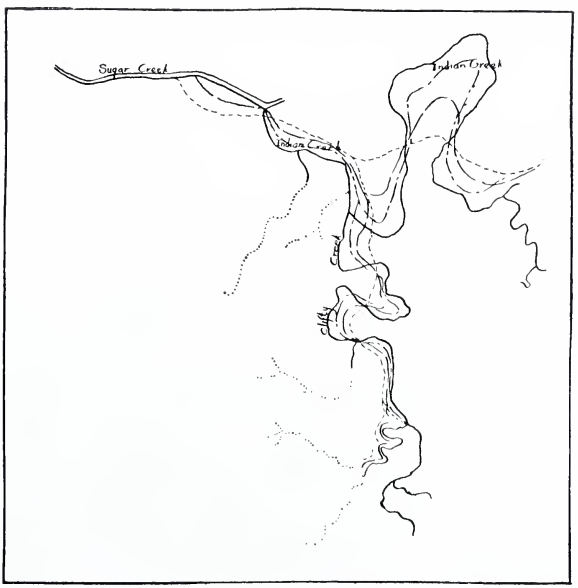


Fig. 9.

Run because the Mansfield sandstone is not sufficiently argillaceous to undercut generally in this manner on the outside of curves, although some undercutting is noted. Figure 9 illustrates this theory of the increasing development of a meander pattern from an originally normally winding course in a glacial topography. The incision process is considered to have started at about the 700-foot contour line, as shown by the present topographic map. Intermediate steps in this process are shown by the dashed lines.

The following men helped wholeheartedly in the forwarding of this project:

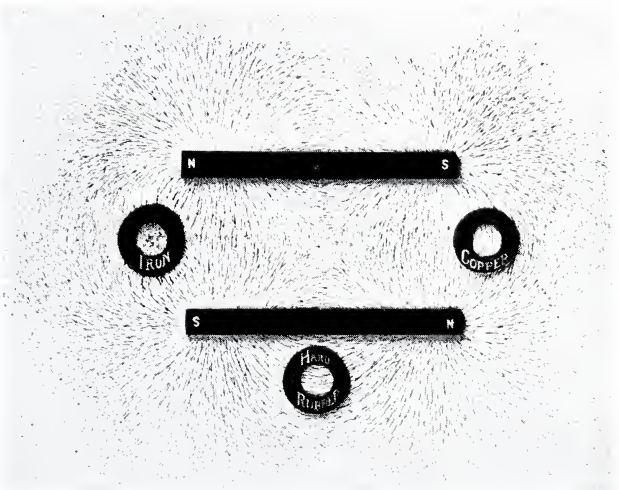
Surveying: D. Baird, B. N. Cooper, R. Gault, Dale Harris, David Harris, M. Harris, T. C. Huestis, E. Miner, L. Osborn, W. Osborn, R. Schlundt.

Photographs: L. Hasselman, L. Marsh, E. Dean.

PERMALLOY FILINGS FOR MAPPING MAGNETIC FIELDS

Arthur L. Foley, Indiana University

In mapping magnetic fields by means of iron filings the field at a short distance from a weak magnet will not be strong enough to orient the filings. The orientation may be produced by the use of a strong magnet. But in that case the field immediately about the magnet is so strong that the filings fly toward and cling to the magnet, leaving a space more or less free from any filings at all. The difficulty can be



partially overcome by using filings of permalloy instead of iron. The magnetic susceptibility of permalloy is far greater than that of iron in weak fields, and is considerably less in strong fields. As a consequence permalloy filings will orient themselves farther from a magnet than will iron filings, and they will not be drawn toward the magnet quite so strongly in the region immediately about it.

The accompanying figure is a field mapped with permalloy filings. Note that hard rubber and copper do not affect the field appreciably, the filings being lined up on the inside of disks (shaped like washers) of these materials just as they would be if the disks were absent. The iron disk bunches the lines of force and there is no field inside. The shielding action of iron is clearly shown.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

Permalloy being rather soft is not readily filed. A rather coarse bastard cut file gives best results.

To overcome the bright metallic luster of permalloy filings so as to make the lines of force stand out more conspicuously, the writer places them in a small beaker and wets them with India ink, stirring them occasionally while they are drying over a radiator.

AUDIO FREQUENCY TRANSFORMER IMPEDANCE

J. B. HERSHMAN, Indiana University

Several writers have developed the theory and equations for ideal transformers[1] having no distributed capacity, no leakage reactance, no eddy current, no hysterisis loss, and no copper losses. These conditions may be approximately obtained in commercial power transformers but not in audio frequency interstage and output transformers.

Some equations developed by the theory of the ideal transformer are not even close approximations. Some experimenters have for example assumed that an output transformer has a constant voltage ratio for all values of input and output impedance. This is not the case as will be shown later. Certain manufacturers print "information" in their catalogues for transformers such as, "primary impedance 15,000 ohms, secondary impedance 40,000 ohms, ratio 3:1." Just what such information is worth is rather hard to understand since such things depend entirely upon frequency, voltage, load, and the relative strength of a-c and d-c currents traversing the coils of the transformer. Other writers[2] neglect entirely any distributed capacity in output transformers. In a general way this may be a safe assumption. Fig. 1 shows that in the case of this particular type of transformer with a step down ratio of 2:25:1, the distributed capacity has some effect on the impedance values of the transformer.

In the bibliography will be found quite a number of references to the theory and operation of transformers. While apparently good theory, in most cases of practical application the predicted and actual results do not agree very well. Part of the variation in transformer theory is due to the assumptions concerning the proper equivalent circuit upon which to base the theoretical equations. No attempt will be made here to reproduce or criticise these circuits varied as they are. A circuit proposed by Webb and Diamond,[3] Fig. 2, seems to agree with the experimental results obtained for open circuit readings. Many practical considerations such as the correct value of inductance, capacity, resistance, reactance, and impedance for various parts of the circuit are difficult to obtain. The difficulty arises from the attempt to isolate such constants as distributed capacity, leakage, and a-c resistance from the inductance values of the coils with which they are associated.

In theory an ideal transformer should transpose a certain load from

[1] (a) R. R. Ramsey, Proc. Ind. Ac. Sci.

(b) K. S. Johnson, "Transmission Circuits for Telephonic Communication." Chapter VI, "Ideal Transformers." See Bibliography, "Audio Transformer Theory."

[2] R. C. Hitchcock and W. O. Osborn, "Output Transformer Design," Part I, "Electronics," Nov., 1930, p. 381. Part II, "Electronics," Dec., 1930, p. 427.

[3] J. S. Webb and H. Diamond, "Testing of Audio Frequency Transformers." Proc. I. R. E., Sept., 1927, Vol. 15, p. 767.

the secondary to an equivalent load in the primary circuit. This effective load should be the impedance of the secondary circuit multiplied by or divided by the transformer ratio n^2, $(n = \sqrt{Z_S / Z_P})$. If the secondary load is a pure resistance then $R = R_P + n^2 R_S$ and $X = X_P - n^2 X_S$. These equations may be found in any standard text on electrical engineering. In an audio frequency transformer such equations apply more closely to the output transformer because the secondary has little distributed

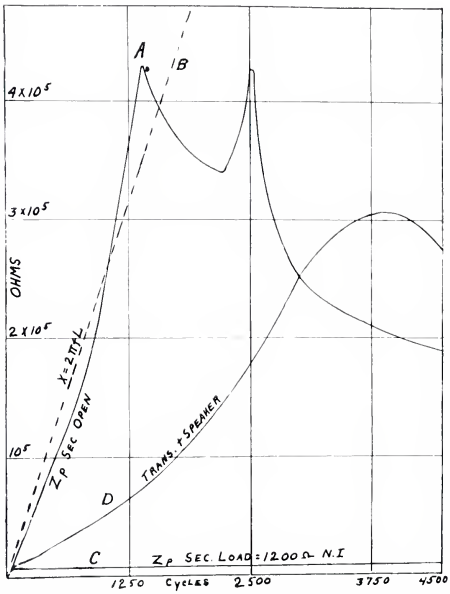


Fig. 1. Impedance curves for output transformer.

capacity, the current is relatively large, the impedance of the load is small in comparison to the input impedance of an amplifier tube, and the primary impedance is ordinarily not as large since the transformer is more often designed for use in the plate circuit of a power tube. In both types of transformers however the primary or secondary resistance in some cases removes a transformer entirely from the ideal class. Kirke[4] in discussing the difference between input and output transformers in a very good article on microphone amplifiers assumes that the only difference in the two types is that the output transformer can be considered free from effects of distributed capacity. In Fig. 2 the various constants are as follows: R_P, primary and secondary resistance and losses; Ll, leakage inductance; L, primary and secondary inductance referred to the primary circuit; C, capacity of primary, capacity of secondary and mutual capacity lumped; R_S, secondary load.

For an output transformer C is small and R_S has a larger effect on primary conditions. In practically all cases the curves of voltage

[4] H. L. Kirke, E. W. and W. E., July, 1928, Vol. V, p. 361.

ratio against frequency gave reasonably flat amplification dropping slightly above 4,000 cycles. These curves for the better types of transformers may be found in the articles referred to in this paper or any of the standard texts on radio. The curves are in most cases taken by using the vacuum tube voltmeter as the measuring device under actual load conditions and as such represent rather faithfully the operation of the transformer. No curves are reproduced in this paper although data has been taken on each transformer used in this study. In the better designed audio transformers, constant voltage amplification seems to be a goal attained by most manufacturers.

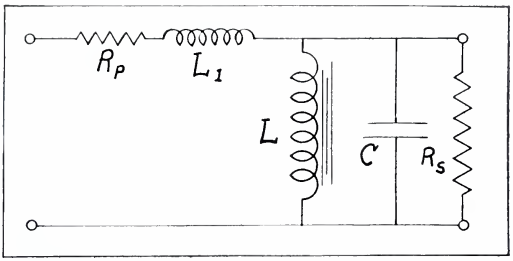


Fig. 2. Equivalent circuit of audio transformer.

Much has been written concerning matching impedances recently. This is for two purposes: first, to obtain maximum power; second, to prevent distortion by reflections. Theoretically, these two objectives are simultaneously obtained if $Z_S = Z_O$, where Z_S is the impedance of the source and Z_O is the input impedance of the transformer.[5] When a condition is set up ($Z_S = Z_O$) such that no reflections occur the value Z_O is known as the characteristic or surge impedance of the circuit. This value as given by Bradfield and John[6] for an impedance network is $Z_O = \sqrt{Z(\text{open}) \times Z(\text{closed})}$ where Z(open) is the impedance of the transfer network with its output terminals open and Z(closed), the impedance with the output terminals short circuited. If an ideal transformer is considered as an impedance network[7] we should obtain the same relation $ZO = \sqrt{Z(\text{open}) \times Z(\text{closed})}$.

The writer decided to see how closely reactance, inductance, and resistance values of actual transformers would agree with those predicted by ideal theory. It was hoped that some information could be obtained concerning the matching of impedances and if "characteristic impedance" had any meaning as applied to the actual transformer in which ideal conditions are not obtainable. (The writer seriously doubts whether ideal conditions would be desirable.)

The remainder of this paper will be divided into two parts, (A) data concerning output transformers and (B) data concerning input transformers.

[5] G. W. Pierce, "Electric Oscillations and Waves," p. 304.

[6] Bradfield and John, "Telephone and Power Transmission," Chapter II.

[7] T. E. Shea, "Trans. Networks and Wave Filters," Chapter 3, and pp. 325-334.

A. Output Transformers

The output transformers used in this study cannot be claimed to be entirely representative of their class because in the writer's opinion such a transformer does not exist. The transformers used were: a Western Electric n = 2.25:1; a Magnavox n = 16:1; and a Silver-Marshall n = 1:1, where n is the average voltage transformation ratio.

Using the transformer 120-C, a transformer designed to couple a 5000-8000 ohm tube to a magnetic speaker, four series of readings were taken. In Fig. 1 is represented graphically the results of these measurements. Curve A is the impedance curve of the transformer 120-C with the secondary unloaded. The maximum value at 1400 cycles represents an impedance of 430,000 ohms. The depression in the curve at 1800 cycles is caused by series resonance between L_1 and the leakage reactance and C the lumped capacity of the transformer. Above 2500 cycles the capacity C which shunts L passes the alternating current.

Curve B is a theoretical value of reactance of the open circuited transformer calculated from the bridge value of 40 henries at 100 cycles. The maximum of reactance at 5000 cycles was 1,250,000 ohms.

Curve C is the measured impedance of the primary with a pure resistance load of 1200 ohms across the secondary. Using a value n =2.25 for the theoretical amplification where $n = \sqrt{Z_P/Z_S}$, then $R_P = R_1 + n^2R_2$. $R_P = 720 + 6080 = 7800$. R_P as measured at 1000 cycles is 7800. Actual measured value of n at this frequency was found to be 2.75. The values of Z_P varied from 7300 ohms at 60 cycles to 8700 ohms at 5000 cycles.

Curve D is the impedance of the output transformer primary with a magnetic (Utah) unit on the secondary. The capacity of the unit seems to pass the current above 4000 cycles. Other output transformers gave practically the same results. Matching impedances with this combination would be an impossible task.

In Tables I and II are shown the data secured by using the circuit shown in Fig. 3. Primary and secondary voltages were read by a V. T. voltmeter. The primary alternating current was obtained by measuring

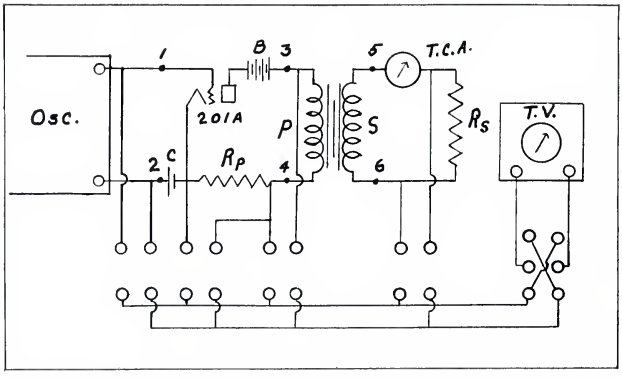


Fig. 3. Measuring circuit for transformer characteristics.

the voltage across a resistance in series with the transformer since $I_{a\text{-}c} = E_{a\text{-}c}/R$. The V. T. voltmeter registers only the a-c voltages. For the data of Table I no tube was used, all current being alternating. For Table II, a 112A tube was connected as shown. The d-c plate current varied from 4.5 to 7.5 mills. It is seen that the current ratio values are more constant and hence more valuable as a basis for transformer computations under all loads. Different primary voltages have but little effect on these ratios but change the impedance values to a large extent.

TABLE I

Voltage and current ratios for 120-C at 60 cycles.

Primary voltage 4.15 volts No d-c No tube

Z_P	R_S	V_S	I_S	I_P	A_I	A_E
ohms	ohms	volts	milliamps			
2350	100	...	3.6	1.76	2.06	...
2800	200	.58	3.05	1.48	2.06	7.15
3300	300	.76	3.50	1.25	2.05	5.75
4200	500	1.02	2.04	.99	2.04	4.06
5000	700	1.13	2.00	.83	2.00	3.66
5700	900	1.27	1.93	.73	1.93	3.26
6800	1200	1.37	1.87	.61	1.87	3.02
7800	1500	1.43	1.79	.53	1.79	2.90
8600	1800	1.55	1.79	.48	1.79	2.68

TABLE II

Voltage and current ratios for 120-C at 60 cycles.

Primary voltage = 4.80 112A tube on primary

Plate voltage = 90 Average plate current = .006 mills

Z_P	R_S	V_S	I_S	I_P	A_I	A_E
ohms	ohms	volts	milliamps			
2800	200	.72	3.60	1.72	2.09	6.65
3300	300	.90	3.00	1.45	2.06	5.34
4000	500	1.21	2.42	1.17	2.02	3.96
4800	700	1.35	1.93	1.00	1.95	3.55
5600	900	1.50	1.66	.85	1.94	3.20
6600	1200	1.67	1.39	.72	1.88	2.88
7500	1500	1.78	1.19	.64	1.86	2.70
8400	1800	1.82	1.03	.59	1.74	2.63

Table III shows the results obtained with the Magnavox output transformer by taking measurements of the primary impedance with the secondary open and closed. The image, surge, or characteristic impedance Z_O was then obtained by

$$Z_O = \sqrt{Z(\text{open}) \times Z(\text{closed})}.$$

TABLE III

Characteristic Impedance

Magnavox output transformer Ep = 1 volt

f cycles	Z (open) ohms	Z (closed) ohms	$Z_0 = (Z_0 \times Z_c)^{\frac{1}{2}}$ ohms
60	.....	....	.....
100	3150	1280	2050
200	6200	1350	2890
300	8930	1340	3460
500	15400	1450	4730
700	20600	1600	5750
1000	29700	1800	7300
1400	42000	2180	9550
1800	56000	2550	12000
2000	65000	2780	13400
2500	91600	3300	17400

If Z_0 is plotted against frequency the curve has a decided rise. It appears that if characteristic impedance is to mean anything definite the frequency should be specified. At 1000 cycles, Z (open) is 29,700, Z (closed) is 1800, and Z_0 is 7300. The transformer current ratio at 1000 cycles is approximately 21. If we divide 7300 by $(21)^2$ or 441 we get a value of 16.5 ohms for X at 1000 cycles. X at 1000 cycles by measurement is 15 ohms. This shows fair agreement, but sufficient work has not been done by the writer to make any definite conclusions concerning the generality of such experiments.

From this section of the paper the writer feels safe in drawing the following conclusions: (a) Output impedance can be matched more nearly by using speaker units of low impedance values in conjunction with high ratio, step-down, output transformers; (b) characteristic impedance can be of use in impedance matching but it is variable, depending upon frequency; (c) current ratios are more constant and furnish a better basis for calculations; (d) the output audio frequency transformer more closely approaches the ideal or perfect transformer than the interstage or input transformer. The basis for this last conclusion will be found in the next section.

B. Input Transformers

The transformers used in this part of the study, all audio frequency intertube transformers, were as follows: Thordarsen, models R-400 and R-300; Sampson 3:1 ratio; Jefferson replacement (dated 11-31); Erla, Concert Grand; and an All-American type R-41, 3:1 ratio.

Data was taken for each of these transformers with the secondary open and no d-c in the primary, a General Radio (25-70,000 cycle) oscillator furnishing the a-c current in all measurements.

Load curves were taken employing circuits Fig. 4 and Fig. 5.

In Fig. 4 the impedameter was connected across Zp. Curves were taken with R_S equal to infinity, .2 megohm and .5 megohm. Various values of C from 0-4.5 volts were used. The tube was a type 201A with

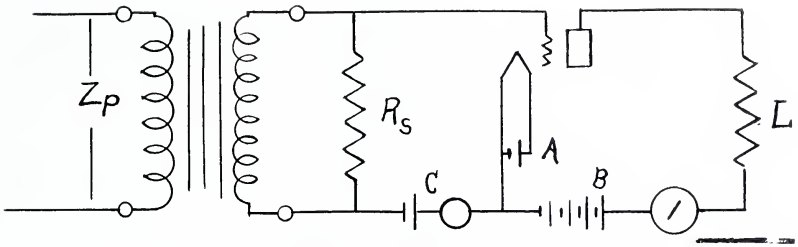


Fig. 4. Transformer circuit for primary impedance.

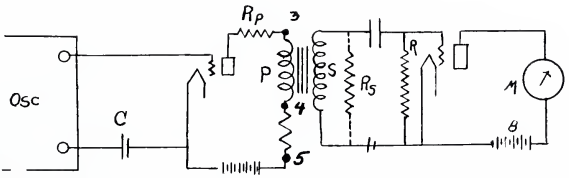


Fig. 5. Transformer impedance measuring circuit.

83 volts on the plate. Under these conditions the amplification factor determined by the dynamic method[8] was 8.2. The a-c grid voltage was determined by measuring the voltage across L with a V. T. voltmeter.

Fig. 6 shows graphically the results obtained. The most important

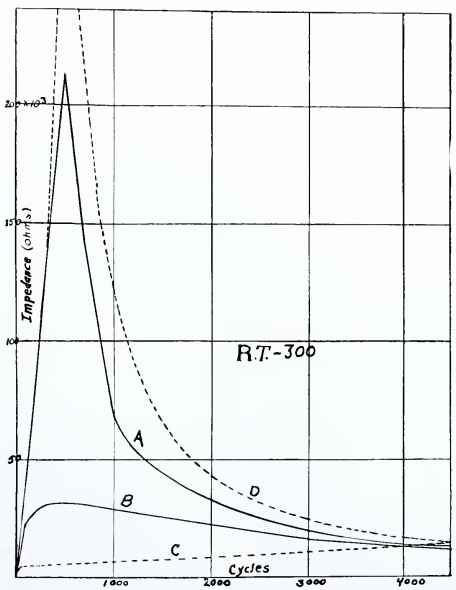


Fig. 6. Impedance curves for interstage transformer.

[8] R. R. Ramsey, "Experimental Radio," p. 77.
H. A. Brown, "Radio Frequency Electrical Measurements," pp. 228-230.

points to be observed are: Curve D, the no secondary load curve, shows definite parallel resonance at 500 cycles with an impedance at this point of 450,000 ohms; Curve A, where the amplifier tube with the current constants is used as load, shows a similar resonance point at 500 cycles with an impedance of 210,000 ohms.

For Curve B conditions were exactly the same as for Curve A, except that a .5 megohm resistance was placed across the secondary of the transformer. This flattens the impedance curve to a great degree.

For Curve C the conditions were the same as for Curve B, except that the grid bias voltage was zero. This allowed a rectified grid current of from 12-25 microamperes to flow through the secondary, thereby reducing its "effective" impedance. This decrease in secondary impedance increased the voltage amplification from 1.28 for Curves A and B to 2.67 for Curve C.

The criticism might be made that the curves obtained by using the circuit of Fig. 4 would not be representative of actual conditions since no direct current flows through the transformer primary. To investigate this point the circuit of Fig. 5 was employed. Contacts 3, 4, and 5 give a means of determining the primary current, voltage, and impedance. $R_P = O$ in this set of readings. The circuit to the right of R_S being a V. T. voltmeter which acted as a load for the transformer, at the same time measuring the secondary voltage of the transformer. The voltage across P was kept constant at .98 volt.

The writer has noticed some written criticism that a V. T. voltmeter does not load an interstage transformer sufficiently. According to E. B. Moullin the input impedance of such a voltmeter, if R (Fig. 5) is 2 megohms, is approximately 1 megohm. The curves obtained with this

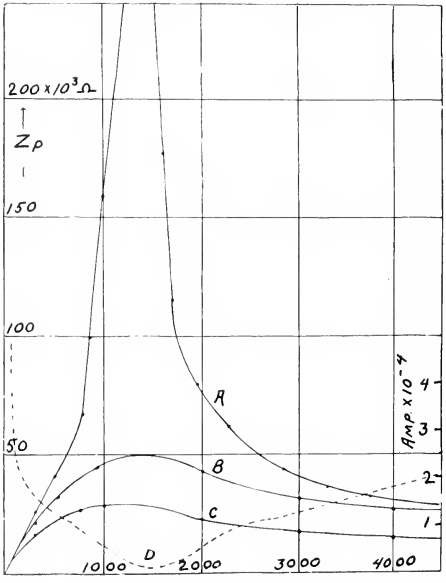


Fig. 7. Series resonance curves.

circuit were almost identical with the curves employing circuit 4. If a 1 megohm grid leak is used in the V. T. voltmeter, the conditions are the same as for a value of $R_S = .5$ megohm in the circuit of Fig. 4. Using the circuit of Fig. 5 a resonant peak was obtained with a Jefferson transformer of 100,000 ohms at 1400 cycles.

Fig. 7 is a series of curves representing values for the Jefferson transformer using the circuit of Fig. 5 for A, B, and C.

In Curve A the $R_S = \infty$, $C = -4.5$. In Curve B, $R_S = .5$ megohm, $C = -4.5$. In Curve C, $R_S = .5$ megohm, $C = 0$.

Curve D of Fig. 7 was obtained by the circuit of Fig. 8. M in Fig. 8 was an output meter to keep the voltage from the oscillator constant at all frequencies, R was 10,000 ohm resistor, T the transformer primary and V. T. V. M. a thermionic voltmeter.

E_R divided by 10,000 gives the current through the transformer primary. In Curve D, 1×10^{-4} amperes is plotted against frequency. At 1400 cycles a minimum current very nearly zero is obtained showing that the impedance of the transformer approaches very high values at this frequency. This again indicates parallel resonance and hence the validity of the equivalent circuit, Fig. 2.

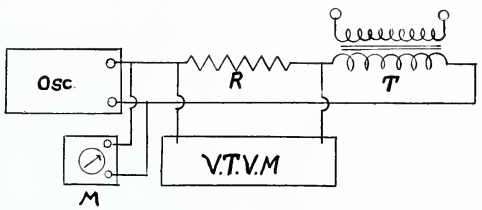


Fig. 8. Current determining circuit for series resonance.

If impedance matching is to have any meaning, input transformers should be loaded with a leak resistance. This loading decreases the effect of distributed capacity by furnishing a lower resistance to be reflected to the primary circuit by the transformer. In short the load resistance causes the transformer to act more nearly as a transformer. For example, the Sampson transformer at 1000 cycles with $C = -4.5$ and a load of .5 megohm has a primary impedance of 56,000 ohms. The ratio being approximately 3:1, a value of 55,000 ohms reflected resistance is obtained by dividing 500,000 by 3^2. Below and above 1000 cycles the value varies from this theoretical amount because of the high capacity of the secondary.

In conclusion of this section it may be suggested that an audio frequency input transformer may be represented by an equivalent circuit as shown in Fig. 2 and that to give more nearly ideal transformer action the secondary should be properly loaded.

CONCLUSIONS

Audio frequency output transformers are more nearly ideal transformers because they have windings of comparatively small resistance and possess a smaller distributed capacity.

The image impedance of a transformer as defined by

$$Z_0 = \sqrt{Z(\text{open}) \times Z(\text{closed})}$$

is a variable, increasing exponentially with frequency.

The current ratio for audio frequency transformers is more constant than the voltage ratio for widely different loads.

The primary impedance of an output transformer is determined almost entirely by the load.

The primary impedance of an input transformer is determined by the load if large, but by the capacity of the transformer with small load or no load.

Ideal transformer equations are of very little practical importance for input transformers.

Impedance matching can be more nearly accomplished by loading input transformers with leak resistances having values from .3 megohm to 1.5 megohms, depending upon the transformer.

The a-c resistance of a transformer should not be neglected in transformer theory.

Equivalent circuits may be drawn to explain observed input transformer operation, but these circuits cannot be relied upon for accurate numerical predictions. This follows from the fact that the mutual inductance, primary capacity, secondary capacity, mutual capacity, a-c resistance, and core losses are all variable factors so interrelated that isolation of their several effects is exceedingly difficult.

BIBLIOGRAPHY

I. Transformer Theory.

1. Diamond, H., and Webb, J. S., Testing of Audio Frequency Transformers, Proc. I. R. E., Sept., 1927, p. 769-791.
2. Dickey, E. T., Proc. I. R. E., p. 687-707.
3. Dye, D. W., The Performance and Properties of Telephonic Frequency Intervalve Transformers, E. W. and W. E., Vol. 1, p. 691-699, 1924.
4. Hitchcock, R. C., and Osborn, W. O., Design of Output Transformers, Electronics, Nov., 1930, Dec., 1930.
5. Johnson, K. S., Transmission Circuits for Telephonic Communication, Chapter VI.
6. Kirke, H. L., Microphone Amplifiers and Transformers, Part I, E. W. and W. E., p. 443, July, 1928, Part II, Aug., 1928.
7. Morecroft, J. H., Principles of Radio Communication, Sec. Edition, p. 905-918.
8. Shea, T. E., Transmission Networks and Wave Filters, p. 81-95.
9. Thompson, J. M., Proc. I. R. E., p. 679-687.

II. Vacuum Tube Voltmeter Theory.

10. Aiken, C. B., J. O. S. A. and R. O. S. I., p. 440, Dec., 1928.
11. Brown, H. A., Radio Frequency Electrical Measurements, Chapter VIII.
12. Hayman, W. G., Wireless World, p. 556, Oct., 1930.
13. Hershman, J. B., Proc. Ind. Acad. Sci., Vol. 38, p. 269-273, 1928.

14. Jarvis, K. W., Proc. I. R. E., p. 673-682, Apr., 1928.
15. Lubcke, H. R., Proc. I. R. E., p. 864, May, 1929.
16. Medlam and Oschwald. E. W. and W. E., Vol. 5, p. 56, Feb., 1928.
17. Moullin, E. B., Radio Frequency Measurements, Chap. IV.
18. Nottingham, J. O. F. I., p. 287, March, 1930.
19. Powers and Alderman, J. O. S. A. and R. O. S. I., p. 348, April, 1927.
20. Turner, H. M., Proc. I. R. E., Vol. 16, p. 799-801, 1928.

Note: Bibliography in the paper of reference 13 gives fourteen references to thermionic voltmeter applications and theory.

III. "Turn Over" Effect.

21. Brown, H. A., Radio Frequency Measurements, p. 270-274.
22. Reed, M., E. W. and W. E., Vol. 6, p. 310-315, June, 1929.

IV. Inductance of Iron Cored Coils.

23. Cosens, C. R., Measurement of Inductance of Iron Cored Coils carrying a direct current, E. W. and W. E., June, 1927.
24. Landon, V. D., A Bridge Circuit for Measuring the Inductance of Coils While Passing Direct Current, Proc. I. R. E., Vol. 16, p. 1771-1775. Dec., 1928.
25. Miller, J. M., Scientific Paper of the Bureau of Standards, No. 351.
26. Morecroft, J. H., Principles of Radio Communication, p. 134-137.
27. Moullin, E. B., Radio Frequency Measurements, p. 477.
28. Turner, L. B., Some Measurements of a Stalloy Core with Simultaneous D. C. and A. C. Excitation, E. W. and W. E., Vol. 4, p. 594, Oct., 1927.

THE DESIGN AND USE OF A PHOTOELECTRIC PHOTOMETER

B. A. Howlett, Rose Polytechnic Institute

The author has found a modification of the instrument described by Morey[1] of such usefulness in the physical or chemical laboratory that a description of its construction, faults, and uses might be of use to his fellow workers.

The photocell used in the circuit is a highly sensitive caesium tube produced by the General Electric Research Laboratories. The bridge amplifying circuit to which the photocell is coupled is similar to one

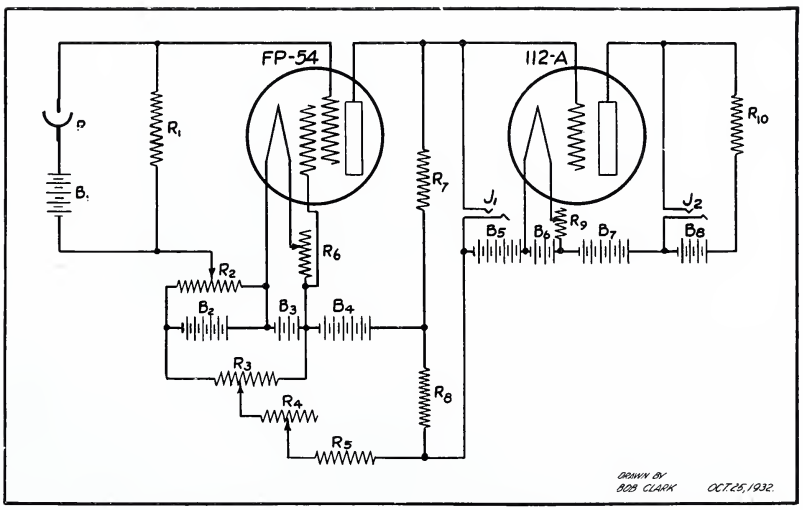


Fig. 1. Circuit Diagram. P, Photocell: R_1, 4.23 x 109 ohms; R_2 and R_3, 400 ohm potentiometers; R_4, 2500 ohm; R_5, 20,000 ohm fixed resistance; R_7 and R_8, 10,000 ohm fixed resistances; R_6, 50 ohm; R_9, 6 ohm; R_{10}, 2500 ohm variable. B_1, 90 volts; B_2, B_3, B_6, 6 volt storage batteries; B_4, 2 volt storage cell; B_5, 9 volts; B_7, 135 volts; B_8, 4.5 volts.

recommended by DuBridge[2]. Fig. 1 shows a diagram of the circuit used. The input resistance, R_1, was made from alundum cement, manganese dioxide and water glass as described by Morey[1]. The circuit consists essentially of an equal ratio arm Wheatstone bridge in which the impedance of the FP-54 tube is balanced by the resistances of R_4 and R_5. R_7 and R_8 are the two equal arms of 10,000 ohms each. The telephone jack J_1 makes it possible to plug in a meter for this preliminary balance.

[1] D. R. Morey, Rev. Sc. Inst., Vol. 3, No. 1, p. 24, Jan., 1932.

[2] Lee A. DuBridge, Phy. Rev., Vol. 37, No. 4, p. 392, Feb. 15, 1932.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

12—48585

A 112-A tube is used to amplify the unbalancing of the bridge due to light falling on the photocell, P. A second jack J_2 allows the connection of a microammeter or galvanometer to read any change in plate current of the 112-A tube, from which the steady current has been balanced by the battery B_8, and the variable resistance R_{10}. All of the circuit except the batteries is inclosed in a heavy brass box, mounted in a brass frame so that it may be rotated around the axis of the optical system. The knobs of R_2, R_3, R_4 and R_{10} extend through one side of the box to facilitate adjustment of the grid and plate voltage of the FP-54 tube, the balance of the bridge and the normal current balance of the plate circuit in the final tube. All batteries are inclosed in a copper box shown to the right in Fig. 2. A large brass tube shields the battery leads between the boxes. Fig. 2 shows the control knobs on the box containing the circuit. This box is slightly tilted to show how it can

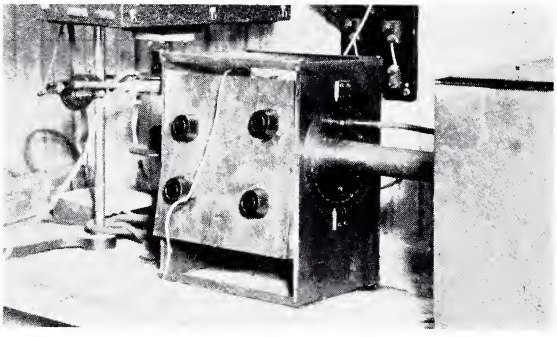


Fig. 2. A view of the instrument with battery box to the right.

be revolved around a horizontal axis. This view also shows a circular scale with verniers which show the angle of tilt to the nearest 5 minutes of arc. The two jacks are also mounted on the back of the scale plate. The figure shows the galvanometer plugged into J_2. Fig. 3 is a general view of the apparatus showing the tube on the left side which may contain a nicol prism or other optical parts between the source and the photocell. In the figure a solution cell is shown in front of the nicol for the study of perpendicular scattering from a vertical beam of polarized light.

In the construction of as sensitive an apparatus as this, great care must be given to high insulation of all grid connections and very careful shielding of all parts. The apparatus has about the same electrical sensitivity as a good quadrant electrometer and must be insulated accordingly. Slight changes in position or size of static charges on insulation or supports cause erratic disturbances. It was found necessary to rigidly support the tubes and make all wire connections rigid enough to maintain their positions when the apparatus was rotated. It was also found necessary to cover all individual battery leads with metal braid, and ground this, to prevent static accumulation on the insulation. The circuit box should be nearly air tight to prevent the drifting of ions on

to exposed parts. With these precautions the circuit becomes stable enough to use a reflecting galvanometer with a sensitivity of 2.53×10^{-9} amperes per mm. The input resistance, R_1, as constructed has a poor temperature characteristic and for the maximum sensitivity of the apparatus should be mounted in a constant temperature box. Magnetic shielding of the box would also be advantageous as the rotation of the box across the earth's field gives noticeable difficulty when trying to find positions of maxima and minima in the study of polarized light.

The uses of such an instrument are many and varied as it combines the properties of a photometer and a polarimeter. Its optical sensitivity as a photometer is such that even with a nicol of only 1 cm. aperture in the optical tube a standard candle at a distance of 10 ft. gave a deflection of slightly over 5 micro amperes. Most photometric readings, even with color filters, could be readily made with a microammeter as the

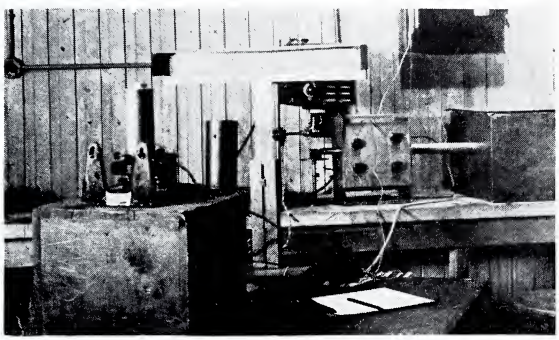


Fig. 3. A general view of the instrument with tube for optical system extending from the left of the box.

measuring instrument. Relatively low intensity spectral lines can be directly compared with the galvanometer in use. This, of course, involves the use of the spectral characteristic of the phototube and its accuracy is dependent on the accuracy of that characteristic. The instrument can be used to measure very minute rotation of the plane of polarization and so has a wide field in chemical research. The author has done considerable work with it in studying the intensity distribution of polarized light scattered from fluorescent and non-fluorescent solutions. It has also been used to measure percentage of polarization of light from such solutions. In this work with low intensities its high sensitivity is very essential.

For student work where the microammeter can be used in place of the galvanometer, the instrument is more simple to operate than an ordinary photometer or polarimeter. It has been used to check the cosine squared law of Malus and to measure the variation of per cent of polarization of light transmitted through a plate at different angles of incidence, besides the usual experiments in polarized light. Its widely variable sensitivity and general stability except under extreme conditions make it a very useful instrument in either a physical or chemical laboratory.

THE EFFECT OF SPACING AND AREA OF ABSORBER ON THE ABSORPTION OF ACOUSTICAL MATERIALS

JAMES F. MACKELL,* Indiana University

INTRODUCTION

In an excellent paper by Edgar Buckingham[1] the theory of decay of sound in reverberant rooms is derived, and the theory underlying measurements of absorption coefficients of materials is discussed at some length. Other similar derivations are due to Jaeger[2], Franklin[3], Eckhardt[4], and the pioneer work of W. C. Sabine[5], who founded the science of Architectural Acoustics.

The formula for decay of sound in a room, as developed by Buckingham is

$$aS = \frac{4V}{Ct} \log \frac{Do}{D} \quad \ldots\ldots (1)$$

where S = area of the surface exposed to sound,
aS = absorbing power of the room,
D = volume density of the sound energy at time, t,
Do = the steady (initial value of D),
V = volume of the room,
C = velocity of sound at the temperature of the room,
a = coefficient of absorption.

If we let t_1 be the duration of audibility of the residual sound when $D_0=D_1$, and t_2 the corresponding time when $D_0=D_2$, the final value of D being that of minimum audibility, it is shown by Buckingham that D_1/D_2 may be set equal to E_1/E_2 where this latter quantity is the ratio of the powers of two known sources. The equation then reduces to

$$aS = \frac{4V}{C} \log_e \frac{E_1}{E_2}\left(\frac{1}{t_1 - t_2}\right) \quad \ldots\ldots (2)$$

The theory discussed applies to the ear method of measuring reverberation time, using the threshold of the ear as a standard fixed reference point. In order to adapt the theory to instrumental practice it is necessary only to have some means of determining the exact time

* This paper is part of a thesis for a Ph.D. degree at Indiana University in the Department of Physics, 1932.

[1] Edgar Buckingham, U. S. Bureau of Standards, Scientific Paper No. 506, May 26, 1925.

[2] C. Jaeger, Wiener Sitz. Ber., Vol. CXX, 2a p. 613, 1911.

[3] W. S. Franklin, Physical Review, Vol. 10, p. 372, 1903.

[4] E. A. Eckhardt, Journal Franklin Institute, June, 1923.

[5] W. C. Sabine, "Collected Papers," Harvard University Press, 1922.

when the sound decay passes a certain point corresponding to E_1 and some later time corresponding to E_2. If for example a sound has been maintained in the empty room for a time sufficiently long for equilibrium to have been established, and it is then suddenly cut off, and if it requires a time t_1 for the sound intensity to pass the level E_1, and a time t_2 for it to pass the level E_2, the value for a_1 (the average coefficient of absorption of the walls, floor and ceiling of the room) is given by

$$a_1S_1 = \frac{4V \times 2.3 \log_{10} (E_1/E_2)}{C(t_2-t_1)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

When absorbing material of area S_2 and coefficient a_2 is added, equation (3) becomes

$$a_1S_1 + a_2S_2 = \frac{4V \times 2.3 \log_{10} (E_1/E_2)}{C(t_2-t_1)} \quad \ldots\ldots\ldots\ldots (4)$$

The reverberation method has been used by P. E. Sabine[6], Watson[7], Chrisler and Snyder[8], and others to measure the coefficient of absorption of standard materials. Various kinds of instrumental methods have been devised, notably that of Chrisler and Snyder in which oscillograph records of decay curves were made. Chrisler and Snyder describe also a more simplified apparatus which gives experimental values in good agreement with oscillograph records. These instrumental methods of measuring absorption coefficients eliminate the ear as a factor of probable error, but in some instances the apparatus is quite complex, and it might appear that other sources of possible error are introduced which would compensate for the possible error eliminated by discarding the ear as a device.

In making measurements of absorption coefficients it is customary to use large blocks of from 25 square feet to 100 square feet of material spread in a compact area on the floor of the room, since it has been demonstrated by many observers that the position of the material in the room does not materially affect results except in unusual circumstances not usually met in test rooms. P. E. Sabine found, however, that in the case of one certain material tested by him, an appreciable area effect was noted, smaller areas giving abnormally large measured values for absorption coefficients. This effect has been reported by Parkinson[9] also. In the latter case, however, Parkinson observes that the effect is not present in the case of frequencies 256 or 128 for the one material which he studied in detail.

Since the area effects described by Sabine and Parkinson did not agree in every particular, especially in the case of the lower frequencies, and since it was felt that some theoretical significance might be attached to the effect especially as regards wave length, it was thought advisable to investigate the phenomenon somewhat thoroughly, using several kinds of materials and different test rooms as well as different methods.

[6] P. E. Sabine, Journal Franklin Inst., Vol. 207, No. 3, March, 1929.
[7] F. P. Watson, Univ. Illinois, Eng. Ex. Sta. Press, Bull. 172, Nov., 1927.
[8] Chrisler and Snyder, Bur. Stand. Jour. Research, Vol. 5, Oct., 1930.
[9] John S. Parkinson, Jour. Acoustical Soc. of Am., Vol. 11, July 1, 1930.

APPARATUS AND PROCEDURE

Two reverberation rooms were available, in one of which it was decided to use a simplified instrumental method devised by the author[10] and in the other room the ear method. A check on the results was thus afforded. Three different types of commercial absorbing material were used in the experiment (B. B. Celotex, Balsam Wool, and Sanacoustic Tile). Standard metal organ pipes of frequencies 128, 256, 512, and 1024 were used in each room. These pipes were blown by air under a constant pressure of 3 cm. of mercury. The temperature in each of the rooms was kept as near 24° C. as possible during the investigation and the variation was not more than one degree centigrade. The volume of the room in which the instrumental method was used was 2860 cubic feet with an exposed area of 1242 square feet. The other room had a volume of 3876 cubic feet and an area of 1600 square feet. Both were basement rooms with concrete floors and plastered walls and ceilings. The room in which the instrumental procedure was used had one heavily insulated door and no windows. The other room had a single window and two heavy iron doors.

The instrumental method which was employed is essentially as follows:

Sound is produced in a reverberation room by blowing a metal organ pipe of standard make with compressed air at constant pressure as measured by a manometer. After the sound has been maintained for a time, considerably longer than the reverberation time of the room, the air is suddenly cut off and a sound decay curve is made from points determined by the recording apparatus herein described.

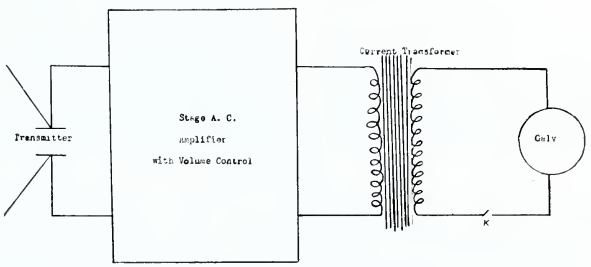


Figure 1.—Diagram of Recording Apparatus

The recording apparatus consists of a Jenkins and Adair condenser microphone[11], the output of which is amplified by a four stage transformer coupled A. C. amplifier as illustrated in the accompanying diagram, Fig. 1. The output of this amplifier is fed through a volume control potentiometer into a step down current transformer from which it passes to a thermo-couple galvanometer, which reads directly in arbitrary energy units. The observer and all the recording apparatus except the microphone are in a room adjoining the reverberation room. (See also Figures A, B, C and D).

[10] J. F. Mackell, Science, Aug. 28, 1931.

[11] An ordinary double button microphone may be substituted for the condenser type, thus eliminating special batteries. The outfit then becomes all A. C. and quite portable.

In making a determination of sound absorption, a metronome is set vibrating with a certain period. In coincidence with a given click of the metronome the air is cut off by a valve. At some subsequent click (say the second or third) the key, K, is closed, which results in a deflection of the galvanometer. The process is repeated for other settings of the metronome, and of course several readings are taken for each setting to insure a representative average. If, now, the apparatus be calibrated to

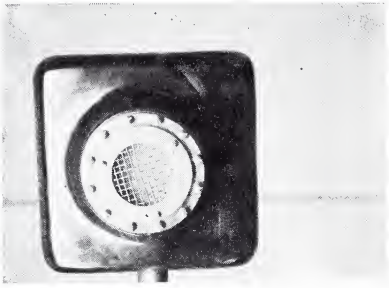


Fig. A.

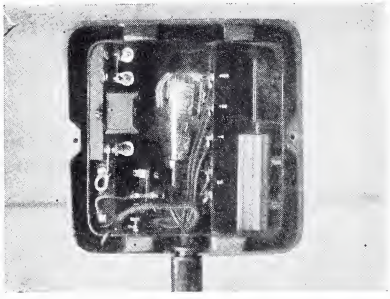


Fig. B.

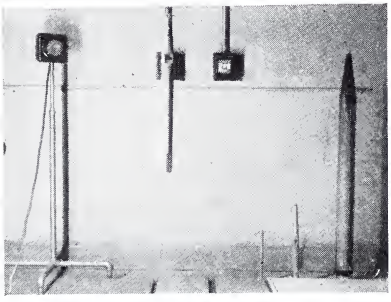


Fig. C.

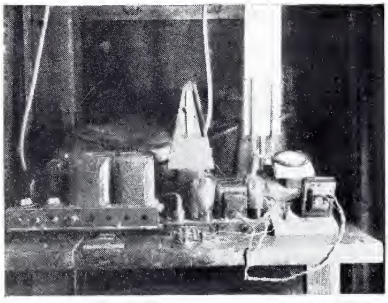


Fig. D.

read in decibels of decay and the output volume control is set accordingly, it is immediately apparent that the values for coefficient of absorption may be obtained from the slope of the curves obtained by plotting values of $\log_m E$ against corresponding values of t. The method of calibration will be described later in this paper.

Figure 2 is a set of curves plotted from data taken as indicated. These curves show the logarithmic nature of the decay quite as well as similar curves obtained by more complicated recording devices. The values of absorption coefficients obtained in this manner have been checked against values for the same kinds of materials found by observers in other laboratories and against values found by the ear method in another room at Indiana University. The agreement is very good in both cases.

It will be noted that the ear is still used in this instrumental procedure, but a coincidence determination is substituted for a duration of

time measurement in the older method. It is obvious that coincidence determinations are capable of a very high degree of accuracy, a conclusion which is borne out by the fact that the points thus determined fall approximately on a logarithmic decay curve.

It was intended at first to make an automatic device to cut off the air, and, at some subsequent time to close the key, but measurements made in the manner described seem to indicate that little or no improve-

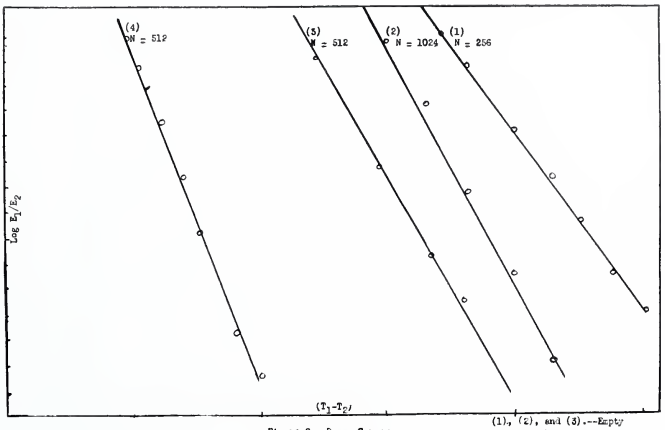


Figure 2.--Decay Curves

(1), (2), and (3).--Empty room values
(4).--Room treated with 30 square feet of material

ment would thus be afforded, probably not enough to warrant the added complication.

It will be noted that thus far the values for E are merely in arbitrary units, and, while the logarithmic nature of the decay curves indicates that the instrument is functioning properly, yet, in order that absolute values for coefficient of absorption of materials may be obtained, it is necessary to calibrate the instrument to read in standard units of decay.

From a study of the decay curves in Figure 2 it is obvious that if the curves be produced to the right and down until they cut the time axis at a point corresponding to the reverberation time of the room for that frequency and respective room condition, we will then be at the threshold value for E.

It was decided therefore to determine by a great number of ear values the average reverberation time of the empty room for an organ pipe of frequency 512 vibrations per second blown at the established pressure. This was done by using a set of head phones in the output circuit of the amplifier just described. About five hundred readings were taken on different days over a period of a week. The average value for the room at this frequency came out to be 4.26 seconds.

The curve for the 512 pipe shown in Figure 2 was then drawn on a suitable scale and produced until it cut the time axis at 4.26 seconds, corresponding to 60 decibels of decay when the output of the amplifier was set so that the slope of the curve was 6/4.26. This was done by trial and error until a satisfactory setting was obtained. Since the

ordinates represent values of $Log_{10}E$, we may now establish the zero ordinate at the threshold value and since reverberation time is defined as the time required for the sound to decay 60 decibels we may establish the 60 decibel point on the vertical axis by producing the curve for the 512 pipe till it cuts the Log E axis. Other curves for the empty room and other pipes should also converge at this point, and the points where they cut the time axis at threshold value for E should give their respective reverberation times. Figure 3 shows how these curves were produced.

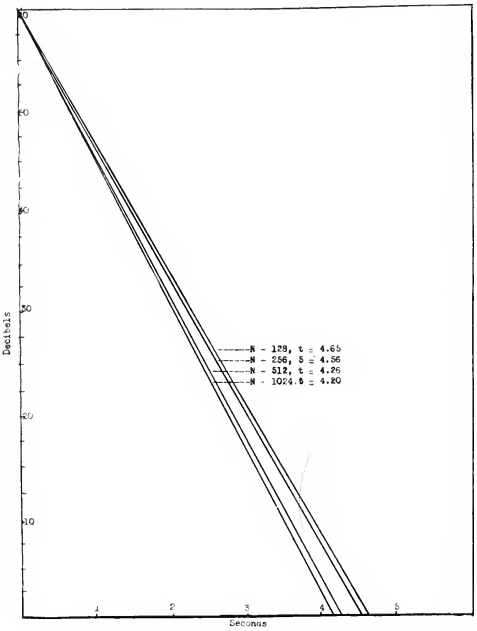


Figure 3.--Calibration Curves for Empty Room

The galvanometer scale was thus calibrated to read in decibels above threshold value as follows:

100 on galvanometer scale = 38 Db.
10 on galvanometer scale = 28 Db.
1 on galvanometer scale = 18 Db.

In a similar manner the values for the reverberation times for the other pipes were found to be as follows:

For 128 pipe t = 4.65 sec.
256 pipe t = 4.56 sec.
512 pipe t = 4.26 sec.
1024 pipe t = 4.20 sec.

It is thus seen that aside from the determination of the reverberation time of the empty room for the 512 pipe, all the subsequent values were instrumental. It might be added that a check was made at frequent

intervals to establish the fact that the tube constants and other instrumental factors did not vary. This was done by resetting the output of the amplifier to make the decay curve for the 512 pipe in the empty room check with the original curve.

Spacing and Area Effects

As was pointed out in the introduction, the principal purpose of this research was to investigate spacing and area effects upon measured values for coefficients of absorption of materials.

Enough has been said in the preceding paragraphs to indicate the general instrumental method of procedure, and, so far as the ear-reverberation method is concerned, the process of taking data by this method is so generally understood that no explanation is necessary. The latter method was resorted to merely to check results obtained by the instrumental method, and, while different rooms were used for each method, yet conditions as regards temperature, pressure, etc. in the two rooms were made as nearly identical as possible.

In order that a thorough test might be made of area and spacing effects, three kinds of standard absorbing materials were selected, namely B. B. Celotex, Sanacoustic Tile, and Balsam Wool in metal screen containers. The thickness of each material was one inch.

The experimental procedure consisted of first taking a set of readings for the empty room for a given frequency pipe; when this was done a large area of one of the types of absorbing material was placed on the floor of the test room in a compact block and another set of readings was taken; then the material which consisted of small separate blocks of various sizes was spaced in checkerboard fashion leaving open spaces of a certain size, and readings were again taken. Again the size and shape of the blocks, as well as the size and shape of the spaces, were varied and the experiment repeated. The procedure was repeated for each of the frequencies used and for each of the three kinds of materials. The whole experiment was repeated several times for all materials and for all frequencies over a period of about three months, and the data submitted are in the main averages of many individual readings.

The organ pipes were suspended from the ceiling by a long cord, so that they could be set swinging in pendular fashion while readings were being taken. This was done to break up any sound pattern which might be present. It was found, however, that this pattern effect was negligible in so far as it affected results in the present procedure. This was true because no readings were taken until about one second after the sound was cut off, and by that time whatever pattern had been in the room had long since collapsed. In fact our measurements indicate that the pattern collapses almost immediately after the source is cut off; so it appears that the very elaborate devices used by some observers to prevent the formation of patterns in a test room are needless so far as reverberation time measurements are concerned. This is particularly true, however, when the method used is of an instrumental type, such as the one used in this experiment, since the pattern has had time to collapse before the first reading on the instrument is taken. In the

case of the ear method, in which the ear of the observer is the sole judge of reverberation time, a psychological factor may enter, so that the presence of a pattern at the time when the decay sets in may to some extent modify results, but observations made in this experiment with the ear method indicate that the influence of patterns upon results is not of major importance.

Since the edges of absorbing materials when the materials are divided into separate blocks would add materially to the area of absorbing surface, the edges in the present case were covered with metal. In the case of one of the materials used a special type of metal container was furnished by the manufacturer and in the other two cases galvanized iron containers were made to fit around the blocks. Therefore none of the observed increment in absorption due to spacing may be attributed to an edge effect.

RESULTS AND DISCUSSION

An inspection of Tables I, II, and III will show that the spacing effect is quite decided in every instance, even in the case of the lower frequencies, for all the materials. In the case of the lower frequencies the effects are of lower order of magnitude numerically but of as high order from the standpoint of per cent of increase.

Judging from the data submitted there seems to be a relation between wave length and the spacing necessary to give maximum effect. This is especially noticeable in the case of frequencies 128 and 256 in which cases the effect was not noticeable until spacing of a half wave length prevailed. This may partially account for the fact that Parkinson did not get the effect for these frequencies.

P. E. Sabine attempted to explain this spacing and area effect from the standpoint of diffraction and screening. It occurred to us, however, that an effect so large as this should be investigated further in an effort to ascertain if any other factors might contribute to its existence.

An auxiliary experiment was therefore attempted in an effort to explain the effect. A small block of the material was placed on the floor of the test room, and the microphone was set at a distance of 10 feet from the material and at a height of about 6 inches from the floor. The organ pipe was blown for a few seconds and then shut off. After an interval of about 1.5 seconds a reading was taken. This procedure was repeated several times; the microphone was gradually moved up toward the block of material, readings being taken at intervals of about 1 foot. Finally the microphone was placed upon the block of material and readings taken. The experiment was repeated with the microphone in a plane 1 foot from the floor, 2 feet from the floor, and 3 and 4 feet from the floor. This procedure was repeated for all the pipes used and for each kind of material and for blocks of areas from 4 square feet to 9 square feet. Some results of this experiment are shown in Table IV.

Since the values recorded by the microphone in the cases just mentioned are values for sound pressures in horizontal planes only, it was thought advisable to repeat the experiment by setting the absorbing material against a wall and attempting to get similar values in vertical planes. This was done in a manner exactly similar to that followed in the former case and some values obtained are recorded in Table V.

Experimental evidence presented indicates that something similar to the energy transfer in an electric or magnetic field is taking place here, and that a theory analogous to Maxwell's Theory of Stresses and Strains in Faraday tubes of induction will explain the phenomenon.

Let us assume that the sound energy density in the room at points far away from the absorbing medium is uniform and that the stream lines in all directions are equidistant. In other words we have a uniform field of three dimensions. For simplicity let us consider the stream lines from ceiling to floor only. At points far away from the absorber, the vertical field is uniform, but as we approach the absorbing slab the stream lines converge due to the fact that sound is being absorbed by the medium and energy will thus flow into the absorber in greater quantities due to a resultant force in that direction. In order that equilibrium may be again restored, it is necessary to assume with Maxwell that a stress is applied on the lateral faces of the tubes of force in such a way that the upward component of this force will be just equal and opposite to the force causing energy to flow to the absorber. A simple derivation due to Starling[12] shows that the pressure necessary to produce equilibrium is $2\pi D^2$ where D is the displacement or the number of tubes per square centimeter.

The regions in the vicinity of an absorbing medium should thus be somewhat devoid of stream lines and should show a low energy density or sound pressure measurement as experiment indicates. The points immediately above or in front of an absorber should also show low values for energy density or sound pressure. This is also true by experiment. The values for the rest of the room should be somewhat higher to maintain the flow of energy to the absorber and this is also indicated by experiment.

It thus appears that if small areas of sound absorbing material be spaced at intervals, a greater absorbing power might be expected than if the material were grouped in a compact area. Theory indicates that this effect should increase as the absorbing units are made smaller and as the spacing increases. However, since the absorption coefficients of materials for the sounds of longer wave length are quite small, a much larger spacing should be considered necessary to achieve this.

It is undoubtedly true that diffraction effects are present also, since an arrangement of material such as we describe approximates a reflection grating in the case of physical optics. We have the sound energy thus diffracted laterally and as a consequence a greater amount will be absorbed in a given time by the absorbing material. Since the diffraction effect is a function of wave length and grating spacing, we may expect results similar to those we found in this experiment. It is improbable, however that all this observed effect may be attributed to diffraction; it appears more likely that the phenomenon is due to a combination of the two effects described above.

Conclusions

The experimental evidence presented in this paper as regards spacing effects in the measured values for coefficients of sound absorption might result in a few conclusions as follows:

[12] S. S. Starling, "Electricity and Magnetism," pp. 133-136.

1. Measured values for coefficients of absorption are very materially dependent upon the size of the sample being tested and upon the spacing between the several units.

2. The measured values increase with the size of the spacing in a manner which depends somewhat upon the wave length of the sound being measured. In general no great increase is perceptible after the spacing has reached ½ wave length of the sound concerned.

3. The spacing effect is present for all wave lengths studied and the order of magnitude of the per cent of increase is as great for the lower frequencies as for the higher.

4. A decided saving in the amount of absorbing material necessary to improve the acoustics of a room might be effected by properly planning the spacing of materials.

5. The spacing effect is not a function of the material since the three materials used are quite dissimilar in composition and yet the effects are practically the same for each material.

6. Subsidiary tests, placing the microphone on the floor and on a stand near the wall and varying its position relative to blocks of absorbing material, serve to substantiate the theory that the presence of absorbing material affects the region adjacent in that the material becomes a sink for sound energy which would have been incident upon the region affected had the absorbing material not been present. This fact together with the well known increment expected due to diffraction may account for the phenomenon observed.

ACKNOWLEDGMENT

Acknowledgements are due to Professor Arthur L. Foley, Head of the Department of Physics, Indiana University, who suggested the problem and contributed valuable counsel during the time the research was in progress. To Professor R. R. Ramsey, who proposed some of the details of the electrical system, and to other members of the physics staff, who were always eager to contribute valuable criticism, the author expresses his sincere gratitude.

TABLE 1.

Data for 25 Square Feet of Balsam Wool by Two Methods. (Subscript 1 Indicates Instrumental Method in One Room and Subscript 2 Indicates Ear Method in Another Room)

	Absorption Coefficient at Frequency							
	128_1	128_2	256_1	256_2	512_1	512_2	1024_1	1024_2
25 sq. ft. Compact, No Spacing	.14	.19	.22	.28	.60	.66	.60	.72
1 x 1 spaced 6 inches	.12	.17	.21	.29	.67	.67	.72	.79
1 x 1 spaced 1 foot	.12	.17	.24	.29	.74	.78	.78	.79
1 x 1 spaced 2 feet	.13	.18	.38	.41	.78	.82	.81	.84
1 x 1 spaced 3 feet	.15	.17	.41	.44	.80	.82	.81	.92
1 x 1 spaced 4 feet	.21	.24	.41	.47	.81	.81	.81	.97
2 x 2 spaced 6 inches	.11	.15	.25	.32	.62	.64	.71	.74
2 x 2 spaced 1 foot	.12	.14	.30	.32	.77	.79	.82	.84
2 x 2 spaced 2 feet	.11	.14	.41	.47	.82	.84	.81	.85
2 x 2 spaced 3 feet	.14	.16	.41	.46	.84	.86	.81	.88
2 x 2 spaced 4 feet	.19	.21	.44	.48	.81	.84	.80	.92
$2\frac{1}{2}$ x $2\frac{1}{2}$ spaced 6 inches	.13	.20	.27	.32	.65	.74	.73	.84
$2\frac{1}{2}$ x $2\frac{1}{2}$ spaced 1 foot	.12	.19	.27	.33	.87	.84	.81	1.05
$2\frac{1}{2}$ x $2\frac{1}{2}$ spaced 2 feet	.16	.19	.39	.44	.87	.84	.80	1.05
$2\frac{1}{2}$ x $2\frac{1}{2}$ spaced 3 feet	.17	.17	.40	.44	.86	.88	.82	1.00
$2\frac{1}{2}$ x $2\frac{1}{2}$ spaced 4 feet	.22	.23	.41	.40	.88	.86	.80	1.04

TABLE 2.

Data for 20 Square Feet of B B Celotex by Two Methods. (Subscript 1 Indicates Instrumental Method in One Room and Subscript 2 Indicates Ear Method in Another Room)

	Absorption Coefficient at Frequency							
	128_1	128_2	256_1	256_2	512_1	512_2	1024_1	1024_2
20 sq. ft. Compact, No Spacing	.12	.14	.26	.30	.65	.72	.65	.72
1 x 1 spaced 6 inches	.11	.12	.27	.31	.66	.71	.80	.92
1 x 1 spaced 1 foot	.13	.15	.27	.32	.78	.89	.82	.91
1 x 1 spaced 2 feet	.14	.15	.44	.47	.79	.99	.83	.94
1 x 1 spaced 3 feet	.15	.17	.46	.47	.82	1.04	.80	1.01
1 x 1 spaced 4 feet	.18	.21	.45	.50	.81	1.02	.82	1.03
2 x 1 spaced 6 inches	.11	.15	.27	.32	.67	.71	.78	.82
2 x 1 spaced 1 foot	.11	.14	.28	.29	.70	.70	.82	.84
2 x 1 spaced 2 feet	.12	.16	.41	.44	.82	.81	.84	.98
2 x 1 spaced 3 feet	.14	.17	.45	.47	.81	.93	.84	.99
2 x 1 spaced 4 feet	.19	.20	.48	.47	.84	.88	.84	.98
2 x 2 spaced 6 inches	.12	.16	.27	.34	.73	.81	.78	.80
2 x 2 spaced 1 foot	.11	.17	.30	.32	.86	1.00	.83	1.00
2 x 2 spaced 2 feet	.14	.17	.45	.49	.82	.97	.87	1.01
2 x 2 spaced 3 feet	.15	.18	.47	.49	.83	1.02	.86	1.02
2 x 2 spaced 4 feet	.23	.27	.51	.50	.85	1.03	.85	1.02

TABLE 3.

Data for 30 Square Feet of Sanacoustic Tile by Two Methods. (Subscript 1 Indicates Instrumental Method in One Room and Subscript 2 Indicates Ear Method in Another Room)

	Absorption Coefficient at Frequency							
	128_1	128_2	256_1	256_2	512_1	512_2	1024_1	1024_2
30 sq. ft. Compact, No Spacing..	.13	.15	.30	.27	.67	.69	.63	.63
1 x 1 spaced 6 inches.....	.13	.16	.31	.30	.65	.69	.74	.78
1 x 1 spaced 1 foot.....	.12	.14	.30	.31	.86	.96	.83	.88
1 x 1 spaced 2 feet.....	.11	.15	.43	.45	.85	.92	.82	.86
1 x 1 spaced 3 feet.....	.14	.17	.45	.48	.84	.90	.81	.87
1 x 1 spaced 4 feet.....	.19	.21	.44	.50	.82	.88	.81	.87
2 x 2 spaced 6 inches.....	.12	.14	.27	.31	.63	.67	.74	.67
2 x 2 spaced 1 foot.....	.13	.14	.31	.33	.77	.81	.72	.82
2 x 2 spaced 2 feet.....	.12	.16	.38	.39	.78	.84	.81	.82
2 x 2 spaced 3 feet.....	.13	.15	.40	.44	.78	.84	.81	.82
2 x 2 spaced 4 feet.....	.20	.20	.41	.43	.82	.86	.80	.84
6 x 1 spaced 6 inches.....	.14	.18	.32	.35	.65	.72	.63	.69
6 x 1 spaced 1 foot.....	.12	.17	.37	.35	.79	.78	.78	.88
6 x 1 spaced 2 feet.....	.12	.19	.43	.36	.90	.89	.93	.90
6 x 1 spaced 3 feet.....	.12	.15	.43	.37	.88	.86	.92	.96
6 x 1 spaced 4 feet.....	.18	.20	.40	.37	.86	.82	.90	.93

TABLE 4.

Data Showing Relation between Intensity and Proximity to Material
(t = 1.1 seconds after cut-off)

N = 512

Empty Room E = 90

2½ x 2½ block Balsam Wool on floor. Microphone stationary 4 inches above floor.

Microphone stationary, material being moved		Material stationary, microphone being moved	
6 feet from microphone.....	E = 60	6 feet from material.....	E = 60
5 feet from microphone.....	E = 55	5 feet from material.....	E = 60
4 feet from microphone.....	E = 56	4 feet from material.....	E = 60
3 feet from microphone.....	E = 55	3 feet from material.....	E = 60
2 feet from microphone.....	E = 50	2 feet from material.....	E = 50
1 foot from microphone.....	E = 50	1 foot from material.....	E = 45
6 inches from microphone.....	E = 30	6 inches from material.....	E = 25
3 inches from microphone.....	E = 20	3 inches from material.....	E = 20
On material anywhere.....	E = 40	On material anywhere.....	E = 40

TABLE 5.

Data Showing Relation between Intensity and Proximity to Material
(t = 1.6 seconds after cut-off)

N = 512

Empty Room E = 90

2 x 2 block Celotex in vertical position against wall. Microphone on stand one foot high in vertical position and capable of rotation on a vertical axis 6 inches from wall.

Transmitter vibrating perpendicular to wall		Transmitter vibrating parallel to wall	
8 feet from material	E = 65	8 feet from material	E = 70
7 feet from material	E = 60	7 feet from material	E = 65
6 feet from material	E = 60	6 feet from material	E = 60
5 feet from material	E = 60	5 feet from material	E = 60
4 feet from material	E = 55	4 feet from material	E = 60
3 feet from material	E = 55	3 feet from material	E = 55
2 feet from material	E = 50	2 feet from material	E = 55
1 foot from material	E = 50	1 foot from material	E = 45
6 inches from material	E = 40	6 inches from material	E = 35
3 inches from material	E = 35	3 inches from material	E = 35
In front of center of block	E = 25	In front of center of block	E = 40
In front of edge of block	E = 35	In front of edge of block	E = 40

THEORETICAL AND PRACTICAL SCREEN GRID AMPLIFICATION

WILLIAM A. PARKER, Indiana University

Theoretically a modern screen grid tube will amplify about 400 times, but in practice the average amplification obtained is about 40 or less.

The purpose of this work was an attempt to obtain a greater practical amplification with the screen grid tube.

The amplification is defined as the ratio of the change of plate voltage to the change in grid voltage which produces the change in the plate voltage. This will be worked out from the plate current plate voltage or what is known as the plate characteristic curve Figure 1. The direct current resistance of the tube is E_p/I_p and the alternating current resistance is dE_p/dI_p If the lines were straight and parallel the direct and alternating current resistance would be the same. Since the curves are neither straight nor parallel the plate resistance of the tube to the alternating current will be determined by the position on the curve at which the tube is worked.

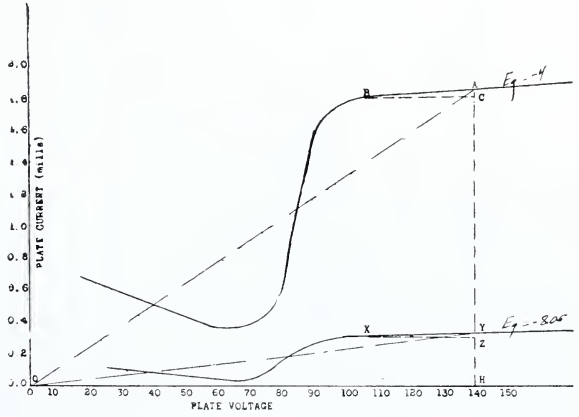


Fig. 1

There is no point on the upper curve at which the direct and alternating current resistance are the same unless the plate voltage is very high. At the point Y on the lower curve the alternating current resistance is of about the same magnitude as the direct current resistance. Therefore with a load resistance equal to the plate resistance of the tube the plate voltage supply of the tube would be only 300 volts in

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

order to have 150 volts on the plate. When the tube is operated with a high negative grid bias the two resistances of the tube are of the same magnitude, but too great a grid bias will make the plate current of the tube too low for it to operate.

If a resistance R is put in the plate circuit of the tube, the impedance of the plate circuit is $R+R_p$. The magnitude of the alternating current set up in the plate circuit due to the alternating grid voltage dE_g acting between the grid and the filament is given by $dI_p = udE_g/(R + R_p)$ and this alternating current flowing through the resistance R gives an available voltage in the plate circuit of $RdI_p = udE_gR/(R+R_p)$. By definition the above expression gives the voltage amplification. Thus the amplification constant of the circuit is $uR/(R + R_p)$. When $R = R_p$ an amplification of ½u is obtained for the circuit. If R was infinity the plate current would be zero, thus it is easily seen that as R increases the plate current decreases, therefore the value of R is limited.

In this work it was found that the tube worked best when the direct and alternating current resistances were the same and the load resistance was of about the same size.

The amplification of the tube was first measured by means of the circuit shown in Figure 2. The amplification constant of the tube measured in this way was approximately 380. Using this circuit the amplification is given by the expression $u=R^1/R$.

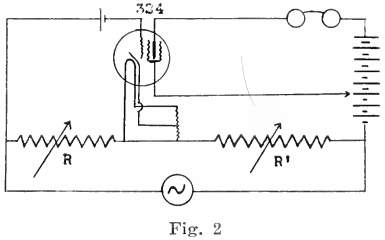


Fig. 2

Since the amplification has been defined as the ratio of dE_p to dE_g, but in this case dEp bears the same relation to R^1 as does dEg to R, because the grid voltage is determined by the voltage drop across R while the changing value of the plate voltage is determined by the voltage drop across R^1. Then if adjustments are made such that a minimum sound is heard in the head set the amplification will be given by the equation $u = dE_p/dE_g = R^1/R$.

The amplification was then measured by the use of a circuit such as shown in Figure 3.

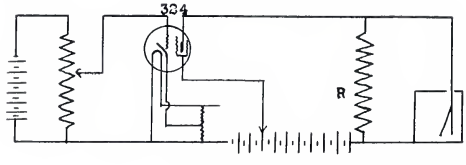


Fig. 3

This method was based upon the change of potential across R (by use of an electroscope which had previously been calibrated) caused by a known change in the control grid potential. Using one megohm for R an amplification of 126 was obtained. Other values of R from .1 to 2 megohms gave smaller amplification factors.

The problem then arose as to the possibility of connecting the 324 to another tube without any great change in the amplification produced by the 324 tube. For this four tubes were tried, a 201A, a 245, a 210, and a 247. The results from the first three tubes mentioned were unsatisfactory, but with the 247 fair results were obtained when coupled as shown in Figure 4 and Figure 5.

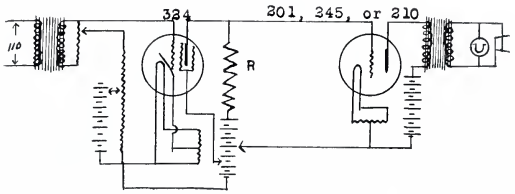


Fig. 4

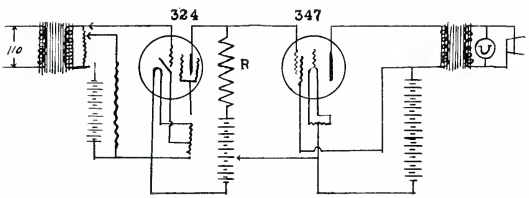


Fig. 5

When the tubes were coupled as shown in Figure 3 it was found that the greatest amplification was obtained with a load resistance of .5 megohm and enough control grid bias such that the plate current was approximately .4 milliampere. The 224 was also coupled to the 347 by means of a transformer, but the results were not very satisfactory, at least not high enough to warrant its use. Impedance coupling also gave poor results.

From the results taken, allowing that the 347 amplifies 90 times, then the 324 has as amplification factor of 130 as a maximum value. Whereas Dowling[1] obtained an amplification of 150 by using the tube with a plate voltage of from 30 to 60 volts.

Figure 5 is a graph showing the variation of the amplification factor due to different control grid potentials for a constant input signal potential.

The output of a phonograph was used as the input during part of this work. The output in watts when the output transformer was connected to a dynamic speaker and a constant frequency record was used as the input the output was about 1.6 watts. Using an ordinary phonograph record for the input the output was about 1.2 watts which

is sufficient to operate three or four dynamic speakers as ordinarily operated for home use.

After obtaining the proper adjustments this circuit works very satisfactorily as a phonograph amplifier or as an audio amplifier, but care must be taken in the coupling of the input in order to prevent the circuit from acting as an oscillator.

It was noted that a very slight change in the plate current from .4 milliamperes was sufficient to cause the 324 to cease functioning as an amplifier.

For experimental purposes this circuit would be very satisfactory for amplifying small signals, but for commercial purposes it is not so well adapted as it is very critical in its adjustments and seems to change with the atmospheric changes. For a large input such that the control grid of the 324 tube left the peak of the grid bias amplification curve the amplification suddenly drops to one-half of its maximum value. Therefore for large input signals unequal amplification would be obtained.

For relatively small variations in the input voltage the variation in the amplification is not noticeable. An examination of the curve shows that over a very narrow range of grid voltage the amplification can be considered as a constant.

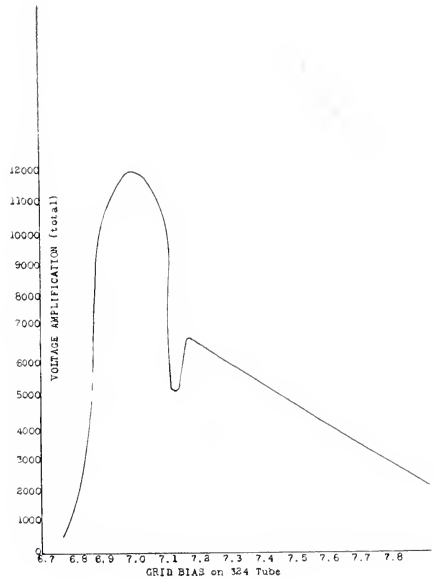


Fig. 6.

BIBLIOGRAPHY

Experimental Wireless & Wireless Engineer, February, 1928. p. 61.

A VACUUM TUBE TUNING FORK DRIVE, USING FORKS OF SEVERAL DIFFERENT FREQUENCIES

HAROLD D. WEBB, Indiana University

The electrically driven tuning fork has been known for some time, but has the disadvantage that the necessary metallic contact with the fork, such as solder or make and break contacts, tends to change the frequency of the fork, and also tends to produce over-tones. A vacuum tube driven tuning fork eliminates this undesirable feature, since no contact with the fork is required, and a pure tone is obtained.

The first vacuum tube tuning fork drive was described by Eccles in 1919[1]. The circuit that he used was very much the same as that shown in fig. 1, if the variable condenser, C, is eliminated. The cir-

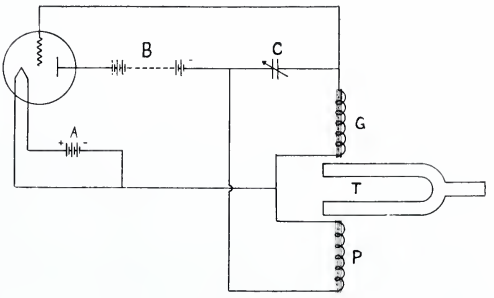


Fig. 1.

cuit consisted of two electromagnets, the windings of the one being placed in the grid circuit, and the windings of the other being placed in the plate circuit, which act upon the prongs of the fork. When the fork is in motion the electromotive force in the grid magnet coil controls the current flowing in the plate circuit and its magnet, the vibrations of the fork being sustained. F. E. Smith[1] found that when a condenser was placed in the circuit, as C in fig. 1, the fork responded more readily.

Butterworth has described the circuit used by Eccles[2], and has done some more work along the same line.

In 1922 Eckhardt, Karcher and Keiser, devised another vacuum tube tuning fork drive which was an improvement over the one described by Eccles[3], and in 1925 Hodgkinson developed another circuit in which no condensers were used[4].

[1] W. H. Eccles, Proc. Phys. Soc., Vol. 31, 1919, p. 269.
[2] S. Butterworth, Proc. Phys. Soc., Vol. 32, 1920, p. 345.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

The circuits that have been devised by previous workers rely more or less upon tuning, or are designed to operate a particular tuning fork of a particular frequency. In the devices described by Eccles, Butterworth, and Hodgkinson the tuning fork is permanently magnetized. In the description of the device used by Eckhardt, Karcher, and Keiser, the magnetic circuit is emphasized. These features are objectionable, because it may be desired to maintain the vibrations of forks of several different frequencies, singly, without changing the circuit in any way other than replacing the tuning fork. It is the purpose of this paper to describe a vacuum tube tuning fork drive which may be used for forks of any desired frequency, within a reasonable range. It is also desirable to make the magnet coil core as short as possible. A circuit is to be described which is so designed that a fork of any frequency, within a reasonable range, may be inserted in the circuit and its variations sustained without the necessity of retuning or changing the circuit in any other manner.

The first circuit to be described can be used for forks of different frequencies by tuning the circuit. The circuit, which is essentially a Hartley circuit, is shown in fig. 1. The grid coil, G, having a laminated iron core, was wound with 5000 turns of No. 36 copper wire. The plate coil, P, was wound in a similar manner. The coils were connected, as shown in the diagram, to the grid and plate of the tube, with a common tap between the coils connected to the negative filament. A variable condenser, C, made up of several fixed condensers and a variable condenser connected in parallel, so arranged that the capacity could be made any value between zero and .1 microfarad, was connected between the grid and plate connections. By leaving coil P fixed, by changing the capacity, and by varying the distance of coil G from the fork prong, the oscillations of the circuit may be brought to the same frequency as that of the fork. When the circuit is in resonance with the frequency of the fork, the fork will vibrate freely, the vibrations being sustained.

The value of C using a 201A tube and a tuning fork of 256 cycles was of the order of .047 microfarad. A Western Electric VT2 tube was found to be satisfactory, as well as a 201A tube. A 112 tube, and a 171 tube were tried with no results, and it was concluded that a tube, in order to be used in the above circuit, must be a good oscillator.

The theory of the circuit is as follows. Suppose the circuit to be oscillating at the same frequency as the frequency of the fork. In that condition there will be an alternating current in the plate circuit superimposed upon a direct current in such a manner that the current is in no case negative, but rises to a maximum value and falls to a minimum. When the current rises to a maximum a magnetic flux is set up in the core of the coil P which causes the core to attract the fork prong next to it. When the current falls to a minimum the magnetic flux is diminished, so that the prong is released and moves to the position farthest from the coil P. The current in coil P again rises to a maximum, the fork prong is again attracted, and the vibrations of the fork are sustained.

[3] E. A. Eckhardt, J. C. Karcher, and M. Keiser, Opt. Soc. Am., J., Vol. 6, 1922, pp. 949-957.

[4] T. G. Hodgkinson, Proc. Phys. Soc., Vol. 38, 1925, pp. 24-33.

It is thus seen that the oscillations of the circuit must be in resonance with the frequency of the fork for the vibrations to be sustained.

The circuit is rather simple to construct, but has the disadvantage that the tuning is very sensitive. The tuning fork must be made of a magnetic material.

When one stage of amplification is used in the circuit of fig. 1 the amplitude of vibration of the fork is greater, but the circuit modified in this manner is more sensitive to tuning than that of fig. 1. The value of C is somewhat less with one stage of amplification.

In an attempt to get the circuit desired the primary of a low impedance output transformer was connected in place of coil P of fig. 1, to the secondary of which was connected a small coil having 500 turns of No. 36 copper wire. While the plate current is increasing an electromotive force will be set up in one direction in the coil when the transformer arrangement is used, thus setting up a magnetic flux in the core

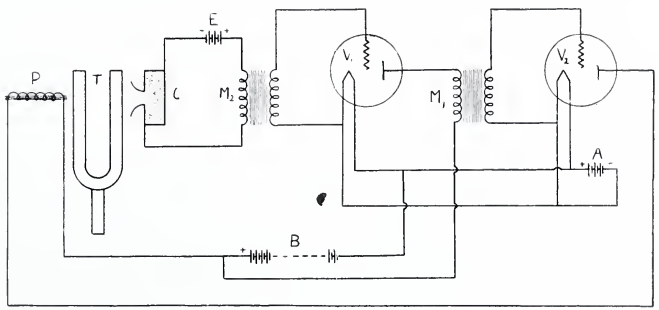


Fig. 2.

of the coil and while the plate current is decreasing an electromotive force is set up in the opposite direction, setting up a magnetic flux in the core. Thus, since the tuning fork is not permanently magnetized, the fork prong will be attracted by the coil core when the plate current is increasing and also when the plate current is decreasing. The circuit must be oscillating at a frequency equal to one-half that of the fork for the vibrations to be sustained. This transformer arrangement was not successful.

The circuit which fulfilled the requirements of the problem is shown in fig. 2. In it no tuning is required. A carbon button microphone is connected in the grid circuit of V_1 through a microphone transformer, M_2, of ratio 30 to 1. The potential E is about 6 volts. V_1 is coupled to V_2 by means of an audio frequency transformer, M_1, of ratio 3½ to 1. The coil P was wound with 5000 turns of No. 36 copper wire. The core was made up of iron wire. Coil P is connected in the plate circuit of the tube V_2. The tuning fork T was placed between the coil P and the microphone C, as shown in fig. 2. The B potential was near the maximum rated value for the tubes used. 201A tubes were first used in the arrangement.

When sound waves are incident upon a carbon button microphone the pressure thus exerted upon the carbon particles changes the resist-

ance of the microphone, and thus the resistance of the circuit. Suppose now that the fork has been set into vibration. The sound waves of the given frequency will change the resistance of the microphone circuit from a maximum to a minimum value for each vibration of the fork. A change of resistance in the grid circuit of the tube V_1 will cause a change in the grid potential. When the potential on the grid is increased the plate current of the tube V_2 will be increased, and when the grid potential is decreased the plate current of V_2 will be decreased, so that the current in coil P will rise to a maximum and fall to a minimum, always remaining positive, for each cycle of the sound wave entering the microphone. There will then be a changing magnetic flux in the core of coil P which will be a maximum when the current in the coil is a maximum, at which time the fork prong will be attracted. When the current in the coil is a minimum, the magnetic flux will be a minimum and the fork prong will not be attracted, but will move to its position farthest removed from the coil. The vibrations of the fork will thus be sustained.

The transformer arrangement already described was tried in place of coil P. It is seen from the theory previously given and from that given above that it is impossible to drive the tuning fork with the transformer arrangement.

If the tuning fork is set into vibration the vibrations will build up until a maximum is reached. By changing the position of the microphone and coil with respect to the face of the fork prongs, a position of maximum amplitude of vibration may be found. Sometimes the fork will begin to vibrate of its own accord. At other times it is necessary to start it.

When two 201A tubes were used forks of frequencies 256 cycles, 287.5 cycles, 320 cycles, 341.3 cycles, 384 cycles, 426.7 cycles, 480 cycles, and 512 cycles were used. All of these tuning forks responded quite well, but not equally well, however.

To give maximum output the coil should have the same impedance as that of the plate of the tube V_2. When the plate potential of a 201A tube is 135 volts, the plate resistance is about 10,000 ohms, so that in order to give maximum output, the impedance of the coil should be equal to about 10,000 ohms. The impedance of the coil was measured at several different frequencies on Mr. Hershman's impedance meter. The results are given in the following table.

Impedance of the coil in ohms	Frequency in cycles per sec.
9300	1000
4800	500
2950	300
1090	60

For the range of frequencies used the A. C. plate resistance of a 112 tube is near the impedance of the coil used. When 112 tubes were used in the circuit, the amplitude of vibration of the fork was greater in all cases, as was expected.

The circuit just described, and diagramed in fig. 2, has the following advantages over the circuits previously described for maintaining

the vibrations of a tuning fork: (1) this circuit is untuned, (2) forks of any frequency, within a reasonable range, may be inserted between the microphone and plate coil, the vibrations thereby being sustained without otherwise changing the circuit in any way, (3) the core of the coil is relatively small, and (4) the circuit is easy to construct and operate. It must be remembered, of course, that the fork used in the circuit must be made from a magnetic material.

The author wishes to use this means of expressing his sincere thanks and appreciation to Dr. R. R. Ramsey, who suggested the problem, for his continued interest and help throughout the course of this experiment. I also wish to thank all others who have helped with the work, and who have offered valuable suggestions.

A LIST OF THE COCCIDAE OF TIPPECANOE COUNTY AND THEIR HOSTS (HOMOPTERA)[1]

JOHN M. AMOS, Lafayette, Indiana

1. *Gossyparia spuria* (Modeer, 1778) (European elm scale). On *Ulmus americana* (American elm).

2. *Phenacoccus acericola* King, 1880 (Maple phenacoccus). On *Acer saccharum* (hard maple).

3. *Phenacoccus gossypii* Town. and Ckll., 1898 (Mexican mealy bug). On *Amarantus, Canna, Chrysanthemum, Lantana, Lycopersicum esculeutum* (tomato), *Nerium oleander* (oleander), *Pennisetum ruppelii* (border sage), and *Solanum melongena* (egg plant).

4. *Pseudococcus citri* (Risso, 1813) (Common or short-tailed mealy bug). On *Chrysanthemum, Coleus blumei* var.? (coleus), *Codiaeum* sp. (croton), *Lycopersicum esculeutum* (tomato), *Nepeta glechoma* (parlor or German ivy), *Setaria glauca* (fox-tail), and *Vinca.*

5. *Pseudococcus aonidum* (Linn. 1762) (Long-tailed mealy bug). On *Euphorbia heterophylla* (poinsettia).

6. *Pseudococcus maritimus* Ehrh., 1900 (Baker's mealy bug). On *Cyperus alternifolia* (umbrella plant), and *Euphorbia heterophylla* (poinsettia).

7. *Coccus hesperidum* Linn., 1758 (Soft brown scale). On *Caria papaya* (melon papaw), *Cyperus alternifolia* (umbrella plant), *Hedera helix* var. *variegata* (variegated ivy), *Musa sapientium* (banana), *Polystichum lonchitis* (holly fern), *Ravina africana* (African jungle plant), *Strelitzia reginia* (bird of paradise), and *Vinca major.*

8. *Lecanium corni* Bouche, 1884 (European fruit lecanium). On *Acer negundo* (box elder), *Acer saccharinum* (soft maple), *Betula* sp. (ironwood), *Carya* sp. (hickory), *Cercis canadensis* (rosebud), *Liquidambar styraciflua* (sweet gum), *Platanus occidentalis* (sycamore), *Prunus serotina* (wild cherry), *Ulmus americana* (American elm), and *Vitis vinifera* (grape).

9. *Lecanium fletcheri* Ckll., 1893. On *Thuja occidentalis* (arbor vitae).

10. *Lecanium nigrofasciatum* Pergande, 1898 (Terrapin scale). On *Acer saccharum* (hard maple).

11. *Pulvinaria vitis* (Linn., 1758) (Cottony maple scale). On *Acer rubrum* (red maple), *Acer saccharinum* (soft maple), *Acer saccharum* (hard maple), *Gleditsia triacanthos* (honey locust), *Platanus occidentalis* (sycamore), *Tilia americana* (linden), *Ulmus americana* (American elm), and *Vitis vinifera* (grape).

12. *Saissetia hemisphaerica* (Targ., 1867) (Hemispherical scale).

[1] Contribution from the Department of Entomology, Purdue University. These data were obtained in the preparation of the writer's undergraduate thesis.

On *Nephrolepis exaltata* (Boston fern), *Adiantum* sp. (maiden hair fern), and *Cycas revoluta* (palm).

13. *Saissetia hemisphaerica* (Targ., 1867) (Hemispherical scale). On *Nephrolepis exaltata* (Boston fern), *Adiantum* sp. (maiden hair fern), and *Cycas revoluto* (palm).

13a. *Saissetia oleae* (Bern., 1872) (Black scale). On *Ficus australia* (rubber plant), *Ficus benjamini* (rubber plant), *Ficus utilis* (rubber plant), and *Nerium oleander* (oleander).

14. *Toumeyella liriodendri* (Gmel., 1789) (Yellow poplar or tulip tree scale). On *Liriodendron tulipifera* (tulip tree).

15. *Kermes andrei* King, 1900. On *Quercus alba* (white oak).

16. *Kermes galliformis* Riley, 1881. On *Quercus alba* (white oak).

17. *Kermes kingii* Ckll., 1898. On *Quercus borealis* (red oak), and *Quercus imbricaria* (shingle or laurel oak).

18. *Kermes pettiti* Ehrh., 1899. On *Quercus borealis* (red oak).

19. *Kermes pubescens* Bogue, 1898 (Chestnut oak kermes). On *Quercus macrocarpa* (burr oak), and *Quercus montana* (chestnut oak).

20. *Aspidiotus abietis* (Schr., 1776) (Hemlock leaf scale). On *Tsuga canadensis* (hemlock).

21. *Aspidiotus ancylus* (Putn., 1877) (Putnam's scale). On *Acer saccharum* (hard maple), *Betula alba* (birch), *Cornus florida* (dogwood), *Cornus stolonifera* (red osier dogwood), *Fagus glandifolia* (beech), *Prunus serotina* (wild cherry), *Tilia americana* (linden), and *Ulmus americana* (American elm).

22. *Aspidiotus cyanophylli* Sign., 1869. On *Cyperus alternifolia* (umbrella plant).

23. *Aspidiotus forbesi* Johns., 1896 (Forbers' scale). On *Prunus americana* (wild plum), *Prunus cerasus* (sour cherry).

24. *Aspidiotus hederae* (Vall., 1829) (Ivy or oleander scale). On *Cyperus alternifolia* (umbrella plant), *Cycas revoluta* (palm), *Hedera helix* (English ivy), *Hedera helix* var. *variegata* (variegated ivy), and *Vinca major.*

25. *Aspidiotus juglans-regiae* Comst., 1881 (English walnut scale). On *Acer saccharinum* (soft maple), *Aesculus glabra* (buckeye), *Celtis occidentalis* (hackberry), and *Tilia americana* (linden).

26. *Aspidiotus lataniae* Sign., 1869. On *Asparagus sprengeri,* and *Phoenix* sp. (palm).

27. *Aspidiotus osborni* Newell and Ckll., 1898. On *Quercus borealis* (red oak).

28. *Aspidiotus perniciosus* Comst., 1880 (San Jose scale). On *Crataegus sp.* (haw tree), *Grossularia* sp. (currant), *Juglans nigra* (black walnut), *Maclura pomifera* (osage orange), *Prunus persica* (peach), *Prunus sp.* (plum), *Pyrus communis* (pear), *Pyrus malus* (apple), *Salix* sp. (willow), and *Vitis vinifera* (grape).

29. *Aspidiotus ulmi* Johns., 1896. On *Acer saccharinum* (soft maple), *Gymnocladus dioica* (coffee bean tree), *Robinia pseudoacacia* (black locust), and *Ulmus americana* (American elm).

30. *Aulacaspis rosae* (Bouche, 1834) (Rose scale). On *Rosa* sp. (rose), *Rubus idaeus* (red raspberry), and *Rubus occidentalis* (black raspberry).

31. *Chionaspis americana* Johns., 1896 (Scurfy elm scale). On *Benzoin odiferum* (spice bush), and *Ulmus americana* (American elm).

32. *Chionaspis caryae* Cooley, 1898. On *Carya laciniosa* (shell-bark hickory), and *Nyssa sylvatica* (black gum).

33. *Chionaspis furfura* (Fitch, 1858) (Scurfy scale). On *Juglans nigra* (black walnut), *Pyrus communis* (pear), and *Pyrus malus* (apple).

34. *Chionaspis gleditsiae* Sanders, 1903. On *Gleditsia triacanthos* (honey locust).

35. *Chionaspis ortholobis* Comst., 1881. On *Platanus occidentalis* (sycamore).

36. *Chionaspis pinifoliae* (Fitch, 1855) (Pine leaf scale). On *Picea pungens* (blue spruce), *Pinus resinosa* (red pine), *Pinus* sp. (Himalayan pine), *Pinus strobus* (white pine), and *Pinus sylvestria* (Austrian pine).

37. *Chionaspis platani* Cooley, 1899. On *Platanus occidentalis* (sycamore).

38. *Chionaspis salicis-nigrae* (Walsh, 1867) (Scurfy scale of willow). On *Populus deltoides* (Carolina poplar), and *Salix nigra* (black willow).

39. *Chrysomphalus aonidum* (Linn., 1758) (Circular scale). On *Citrous medica* var. *limon* (lemon), *Cycas revoluto* (palm), *Ficus elastica* (rubber plant), *Jasminum* sp. (jasmine), *Kentia* sp. (palm), *Pandanus* sp. (screw pine), *Phoenix* sp. (palm), and *Ravina africana* (African jungle plant).

40. *Chrysomphalus aurantii* (Mask., 1873) (California red scale). On *Citrous aurantium* (orange).

41. *Chrysomphalus dictyospermi* (Morgan, 1889) (Morgan's scale). On *Dracaena*.

42. *Chrysomphalus obscurus* (Comst., 1880) (Obscure scale). On *Carya* sp. (hickory), *Quercus alba* (white oak), *Quercus borealis* (red oak), *Quercus coccinae* (scarlet oak), *Quercus montana* (chestnut oak).

43. *Diaspis boisduvalii* Sign., 1869. On *Cattleya* sp. (orchid), *Cyperus alternifolia* (umbrella plant), *Kentia* sp., (palm), *Musa sepientium* (banana), *Ravina africana* (African jungle plant), and *Strelitzia reginia* (bird of paradise).

44. *Diaspis echinocacti cacti* Comst., 1883 (Cactus scale). On *Opuntia* sp. (cactus).

45. *Hemichionaspis aspidistrae* (Sign., 1869) (Boston fern scale). On *Nephrolepis exaltata* (Boston fern), and *Polystichum lonchitis* (holly fern).

46. *Phenacaspis spinicola* Dietz & Morrison, 1916. On *Gleditsia triacanthos* (honey locust).

47. *Lepidosaphes beckii* (Newm., 1869) (Purple scale). On *Citrous aurantium* (orange), *Citrous decumana* (grapefruit).

48. *Lepidosaphes gloverii* (Pack., 1869) (Glover's scale). On *Citrous decumana* (grapefruit).

49. *Lepidosaphes ulmi* (Linn., 1758) (Oyster shell scale). On *Acer negundo* (box elder), *Acer saccharinum* (soft maple), *Carya laciniosa* (hickory), *Cornus florida* (dogwood), *Cornus stolonifera* (red osier dogwood), *Fraxinus americana* (ash), *Juglans nigra* (black walnut), *Populus alba* (white poplar), *Populus deltoides* (Carolina poplar),

Prunus serotina (wild cherry), *Salix nigra* (black willow), *Sassafras officinale* (sassafras), *Syringa vulgaris* (lilac), and *Tilia americana* (linden).

50. *Parlatoria proteus* (Curtis) var. *pergandei* Comst., 1843 (Chaff scale). On *Citrous aurantium* (orange), and *Citrous medica* var. *limon* (lemon).

DESCRIPTIONS OF COCCIDAE HERETOFORE UNREPORTED FROM INDIANA (HOMOPTERA)[1]

JOHN M. AMOS, Lafayette, Indiana

1. *Pseudococcus maritimus* Ehrh., 1900 (Baker's mealy bug or the grape mealy bug). (Pl. I, Figs. 2-6).

Adult female.

Size: length 2-4 mm.; width 1.75-2 mm.

Color: Slightly covered with a whitish secretion; body, legs and antennae reddish-brown; margin with short, white filaments which become longer caudally.

Structural characteristics: Body thickly beset with long slender spines; a group of spinerets on margin of each segment in the center of which are two short stout conical spines, the caudal ones being the larger. Antennae 8-segmented and hairy; segment 8 always the longest; segments 4 and 6 subequal and shortest. Legs hairy, well developed, long and slender; a stout spine on trochanter; femur about twice as long as tibia; tarsus about one-third as long as tibia; claw short and stout; digules fine knobbed hairs. Anal lobe prominent; anal lobe spines as long as anal ring setae; anal ring large with six stout setae.

Hosts: *Euphorbia heterophylla* (poinsettia) and *Cyperus alternifolia* (umbrella plant).

2. *Aspidiotus abietis* (Schr., 1776) (Hemlock leaf scale). (Pl. I, Fig. 1).

Scale of female.

Shape: Circular; exuviae nearly central.

Size: Diameter 1.2-1.5 mm.

Color: Very dark grey, approaching black, outer edge may be lighter; exuviae yellowish orange.

Scale of male.

Shape: Length 1.5-2.1 mm., width 1.2 mm.

Color: Similar to female.

Pygidium of female: Median and second lobes well developed, rounded or slightly notched at the apex on the outer side. Third lobe small and acutely pointed. A pair of irregularly fringed plates between the median lobes; two irregularly branched plates between median and second lobe; three such plates between second and third lobes; usually

[1] Contribution from the Department of Entomology, Purdue University. These descriptions were made in the preparation of the writer's undergraduate thesis. All collections were made in the vicinity of Lafayette.

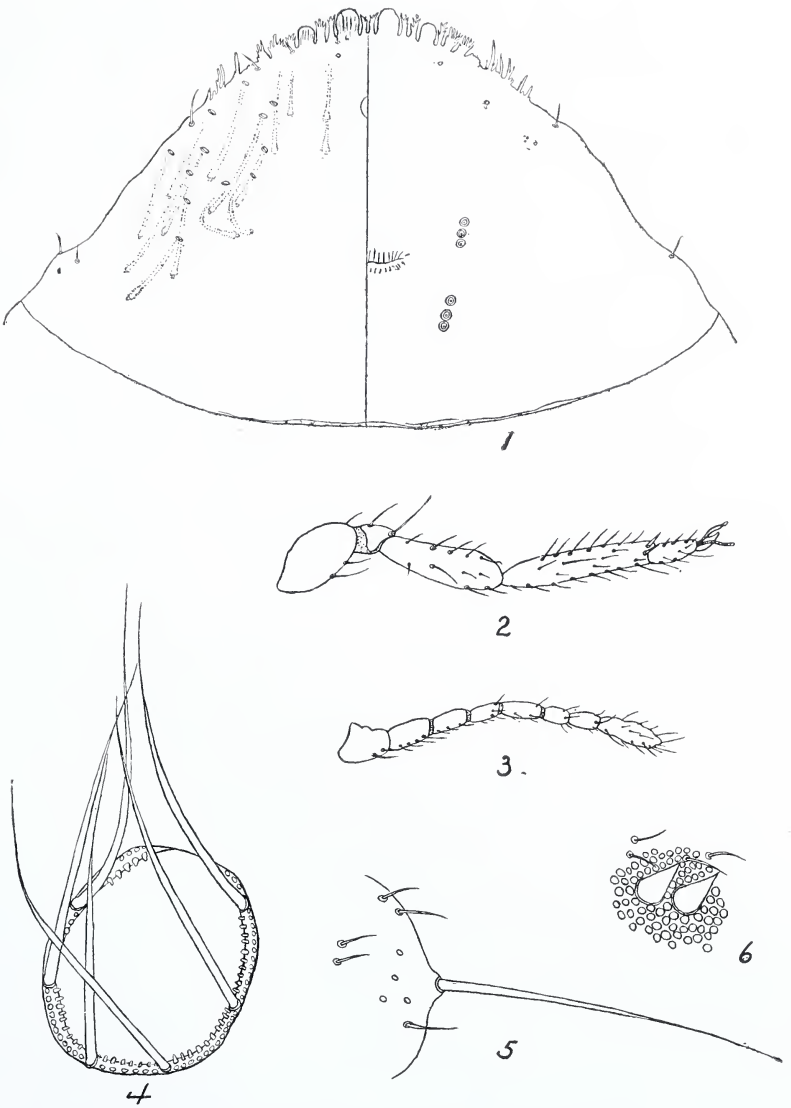


Plate I. Fig. 1—Pygidium of *Aspidiotus abietis;* 2—middle leg; 3—antenna; 4—anal ring; 5—anal lobe; and 6—spines and pores on caudal segment of *Pseudococcus maritimus.*

three plates laterad of the third lobe. Dorsal spines one laterad of each median lobe; one laterad of each second and third lobe, and one laterad of the most lateral plate. Each ventral spine with the exception of the first, which is wanting, is situated laterad of the corresponding dorsal spine. Dorsal gland openings 3-5 in the first row; 6-8 in the second row, 9-11 in the third row. Micropores as in drawing. Median group of

circumgenital gland openings wanting; anterior laterals 3-12; posterior laterals 3-5.

Host: *Tsuga canadensis* (hemlock).

3. *Aspidiotus osborni* Newell and Ckll., 1898.

Scale of female.

Shape: Subovate; exuviae submarginal.

Size: Diameter 1.2-2.1 mm., about one-seventh longer than wide.

Color: Dark, nearly color of host, somewhat similar to *C. obscurus* in general appearance. Exuviae brownish to yellowish orange.

Scale of male.

Shape: Longer and narrower than female; exuviae cephalad.

Color: Similar to female.

Pygidium of female: Median lobes strong and well developed; apex rounded, may or may not be notched on outer side; second and third lobes rudimentary. Margin laterad of plates serrate. Median incision not reaching base of lobes; second and third incisions rather deep and narrow. Of the two chitinous processes at the base of the median incision, the inner one the longest; of the chitinous processes of the second incision, the inner longer than outer; two chitinous processes of third incision equal. A pair of stout spines on the outer base of the median lobe and a pair on the rudiment of the second lobe. The spines of the ventral surface are just laterad of those on the dorsal surface, which are situated as follows: one on each of the three apparent lobes, one about one-third the distance to the penultimate segment, one near the penultimate segment. There are no ventral spines on the median lobes. Dorsal gland openings in three rows; first row 2, second row 4-6, third row 6-10. Median circumgenital gland openings wanting or 2 in number, anterior laterals 5-7; posterior laterals 2-5.

Host: *Quercus borealis* (red oak).

4. *Chionaspis platani* Cooley, 1899.

Scale of female.

Shape: Conically-ovate and slightly convex; generally narrow.

Size: Length 1.8-2 mm.

Color: Dirty white; exuviae pale yellow or brownish located cephalically.

Scale of male.

Shape: Parallel sided to oval in outline; feebly unicarinate.

Size: Length .8-.9 mm.

Color: Dirty white; exuviae yellowish-brown occupying about two-fifths of the length of the scale.

Pygidium of female: Median lobes well developed, moderately divergent and distinctly crenulate on the inner margin. Second lobe well developed with the inner lobule more distinct than the outer; the outer lobule not so broad but narrowed toward the tip; second lobe may be slightly serrate or entire. Inner lobule of third lobe well developed, outer lobule rudimentary. Large conspicuous gland spines arranged as follows: 1, 1, 1, 1, 2-4. The one near the median lobe small and often inconspicuous; others about equal to median lobes in length. Second row of dorsal gland openings consisting only of an anterior group of

3-4 openings. The third row with 4-6 openings in the anterior and 2-4 in the posterior group. Fourth row with 4-8 openings in the anterior group and 4-6 in the posterior group. Marginal gland openings 1, 1-2, 1-2, 1-2. Ventral spines smaller and laterad of corresponding dorsal spines, situated one on each side of the three lobes, one about half way to penultimate segment, and one laterad of the fifth group of gland spines. Median group of circumgenital gland openings 6-13; anterior laterals 10-28; posterior laterals 10-32.

Host: *Platanus occidentalis* (sycamore).

5. *Diaspis echinocacti cacti* Comst., 1883 (Cactus scale).

Scale of female.

Shape: Circular, exuviae nearly central.

Size: Diameter 1.7 mm.

Color: Whitish or yellow green with a contrasting exuviae of dark brown.

Scale of male.

Shape: Narrow and elongate.

Size: Length 1 mm., width .2 mm.

Color: Whitish with yellow or brown exuviae.

Pygidium of female: Median lobes small and entire, widest at middle and diverge caudad from that point. The second and third lobes are bifurcated, the lobules are subequal and parallel. A rudimentary fourth lobe is present with an entire margin but sometimes is serrate. Plates are stout and conical. The first, second, third and fourth are laterad of the first, second, third, and fourth lobes, respectively; the fourth and fifth being nearer together than the others. There is a short projection between the fifth and sixth plates. Ventral surface spines are small and dorsal surface spines are large. Ventral surface spines are situated as follows: the first pair between the median lobes, and are somewhat inconspicuous; the second and third are on the mesal part of the base of the second and third plates, respectively; the fourth is between the fifth and sixth plates, and the fifth is between the seventh and eighth gland spines. On the dorsal surface the first spine is laterad of the first lobe; the second and third on lateral lobules of the second and third lobes, respectively; the fourth mesad of the fourth plate; the fifth laterad of the sixth plate. Laterad of the first, second, and third plates, the margin of the body is prolonged into a papilla which bears an elongate pore.

Host: *Opuntia* sp. (cactus).

INSECTS OF INDIANA FOR 1932

J. J. DAVIS, Purdue University[1]

The winter of 1931-32, following the mild winter of 1930-31, was unusually mild and favorable for the successful hibernation of insects. This resulted in greater abundance of some insects such as the corn earworm, boxelder bugs and scales and a range of destructiveness farther north than heretofore recorded for such pests as the Mexican bean beetle and harlequin cabbage bug.

The mild weather up to and including February, advanced plant growth, many bulbs coming up and reaching the bud stage, while fruit buds were much enlarged. During most of March the temperature was much below normal, in fact it averaged the third coldest March of state record. The cold wave of March froze all green vegetation to the ground and killed all peach fruit buds in southern Indiana.

The remainder of the year up to the present time was not far from normal excepting the marked deficiency of rainfall in May and the excess in September. (Table 1.)

The following insects of economic importance came to our attention during the year:

CEREAL AND FORAGE INSECTS

The European corn borer (*Pyrausta nubilalis* Hbn.) experienced a very unfavorable season and as a result made little progress into new territory and was held without increase over last year in the previously infested territory. Only eight new townships and four new counties (Dearborn, Jasper, Ripley and Tippecanoe) were found to be infested in 1932. As a result of the mild winter of 1931-32, and favorable conditions up to the time the moths emerged and were laying eggs, there was every indication of a notable increase. However, unfavorable temperature and other weather conditions for migration of the moths into new territory and also for larval survival, resulted in the situation noted above. The conditions were so unfavorable that it was surprising to find that the insect held its own in previously infested areas and made some spread. It was impressive in that if the corn borer can survive under the extremely unfavorable weather conditions of 1932, as well as those of 1930, that we must be prepared for alarming increases in intensity and spread if and when a normally favorable or extremely favorable season develops.

The corn earworm (*Heliothis obsoleta* Fab.) showed a marked increase over 1931, doubtless the result of two successive moderate winters.

[1] The writer is indebted to the following persons for records and information contained in this report: H. O. Deay, Geo. E. Gould, G. Edw. Marshall, Geo. A. Ficht, V. R. Diamond, C. M. Packard, R. F. Sazama, John Amos, Paul Ulman and H. K. Rippey.

TABLE 1. Comparative Monthly Weather Data for Indiana, 1932

Month		Temperature		Precipitation		Number of Days		
		State Mean °F.	Departure from normal °F.	State Average Inches	Departure from normal Inches	Clear	Partly Cloudy	Cloudy
January	Normal	28.4		3.13		10	7	14
	1932	38.4	+10.0	5.43	+2.30	9	6	16
February	Normal	30.2		2.52		9	7	12
	1932	39.4	+9.2	1.71	—0.81	12	6	11
March	Normal	40.7		3.75		10	8	13
	1932	34.2	—6.5	2.83	—0.92	8	11	12
April	Normal	51.9		3.56		11	9	10
	1932	51.6	—0.3	2.67	—0.89	13	7	10
May	Normal	62.1		4.06		12	10	9
	1932	62.8	+0.7	1.38	—2.68	16	8	7
June	Normal	71.2		3.86		13	10	7
	1932	72.9	+1.7	4.64	+0.78	14	11	6
July	Normal	75.3		3.38		16	10	5
	1932	76.4	+1.1	3.48	+0.10	19	9	3
August	Normal	73.2		3.34		15	10	6
	1932	74.0	+0.8	3.66	+0.32	17	9	5
September	Normal	67.0		3.24		15	8	7
	1932	66.1	—0.9	5.83	+2.59	16	7	7
October	Normal	54.6		2.74		15	7	9
	1932	54.7	+0.1	3.93	+1.19	13	7	11

It was first reported from the southern end of the state July 1, and frequent reports were received from all sections of the state during the remainder of the season. Sweet and field corn were the most commonly attacked, although other crops, especially green beans and tomatoes, were severely damaged. In the fall this worm attacked chrysanthemum buds and geranium foliage in greenhouses.

Chinch bugs (*Blissus leucopterus* Say) was noticeably more abundant than usual, being moderately abundant during July in Allen, Dekalb and Huntington counties.

Corn root aphid (*Aphis maidi-radicis* Forbes) was abundant and destructive during June and July to sweet corn in several southern Indiana localities.

Clover white grub (*Colaspis brunnea* Fab.) destroyed half of a 30-acre field of corn near Williamsport early in June.

Common stalk borer (*Papaipema nebris* Gn.) was reported as destructive to corn at points scattered throughout the state during

June, July and August. Lily was reported damaged at Urbana, June 8. Apparently less than normally abundant.

Army worm moths (*Cirphis unipuncta* Haw.) were common at lights at Lafayette, May 1, and a student reported finding several moths several nights before. However, no army worm outbreaks occurred according to reports received.

Grasshoppers were not reported common during June and July except at Jasonville, June 14, and at Grabill, July 13, where they were attacking rose buds. Local outbreaks were reported from southern Indiana from July 30 to August 6. On July 30, millions of *Melanoplus differentialis* moved into orchards and corn fields near Vincennes, and by August 6 one year old apple trees had been seriously damaged. One correspondent estimated 90 per cent injury to corn in Vanderburgh County. By the middle of August most of the grasshoppers had apparently been killed by a fungous disease. One report came from Culver in northern Indiana, where alfalfa was seriously damaged August 3. Late in the season, September 4, a report was received from Jasper advising of damage to cabbage. At Bedford, Marshall reports damage to alfalfa, soybeans, garden crops and apple trees during the season.

Saddle-back caterpillar (*Sibine stimulea* Clem.) reported feeding on plum foliage at Evansville, August 18, and a few days later on corn at Mount Vernon.

Hessian fly (*Phytophaga destructor* Say) was the most abundant and showed greater potential destructiveness for a number of years. During June many reports of fallen wheat were received which in itself was evidence of fly abundance. C. M. Packard, in charge of Hessian fly investigations for the U. S. Bureau of Entomology and of the Cereal and Forage Insect Laboratory located at Lafayette, summarizes the situation during the past season as follows: "Spring weather conditions in 1932 favored further fly increase following that of the previous fall, with the result that the spring infestation became the most general and severe in years. The harvest-time survey showed an average infestation of 41 per cent of the stems, with occasional fields greatly reduced in yield. Prospects for heavy fall infestations were very threatening but fortunately did not wholly materialize, for several reasons; low summer survival of puparia in stubble due to desiccation and unusually high summer parasitism; rather unfavorable weather conditions for fall fly activity, namely, shortage of moisture in August and rainy weather in September and October; and generally late sowing, largely on account of delays due to weather but partially at least due to voluntary observance of the safe dates following general publicity of the threatening fly prospect. Early sown fields, though rare, contain heavy infestations, as does volunteer wheat. The main fall emergence was over by the time wheat sown on or after the safe dates had appeared above ground."

Wheat joint worm (*Harmolita tritica* Fitch) was decidedly more abundant than usual in the 1932 wheat crop in north-central Indiana.

Clover leaf weevil (*Hypera punctata* Fab.) was abundant in some localities of central Indiana, reports coming in early in May. However, the outbreaks were checked by a fungous disease before much damage occurred.

Clover aphid (*Macrosiphum pisi* Kalt.) was abundant on clover and alfalfa throughout most of the southern half of the state the last few days in April and early May, being especially damaging to young alfalfa. The chain drag, recommended by Smith in the April, 1932, Journal of Economic Entomology, was used with good results. The outbreak was checked early in May, probably a fungous disease acting as the chief control.

Tobacco flea beetle (*Epitrix parvula* Fab.) was very destructive to tobacco at Lawrenceburg the last of June.

VEGETABLE INSECTS

Harlequin cabbage bug (*Murgantia histrionica* Hahn) was unusually abundant and seriously destructive, the first reports coming in August 15. Heretofore we have no records of the occurrence of this species north of the tier of counties along the Ohio River. The past season reports of damage to cabbage were received from points as far north as Indianapolis, and east to Connersville. Here again the mild winters of 1930-31 and 1931-32 were probably responsible for the temporary extension northward of a typical southern insect.

Imported cabbage worms (*Ascia rapae* L.) were probably more abundant than usual, reports coming from all parts of the state the last of June and the first half of July and again the first half of August.

Cabbage looper (*Autographa brassicae* Riley) was also abundant generally the middle of August.

Cabbage curculio (*Ceutorhynchus rapae* Gyll.) was destructive to hotbed cabbage plants at Connersville and Kewanna, May 23 and 24, respectively. An adult was received from New Albany, June 1, where larvae were earlier damaging cabbage.

Cabbage aphid (*Aphis brassicae* L.) occurred throughout the state and was normally abundant. Early in the season (May 20) several growers reported this aphid abundant and destructive to plants which had been received from Georgia. Indiana growers have been experiencing much trouble with insect infested cabbage and tomato plants, shipped in from southern states, for several years. Growers should refuse such infested material.

Zebra caterpillar (*Mamestra picta* Han.) was abundant on cauliflower at Winamac, June 21.

Striped cucumber bettle (*Diabrotica vittata* Fab.) was very abundant throughout the state, probably more so than normally.

Melon aphid (*Aphis gossypii* Glov.) was apparently less abundant than usual, although some reports of damage were received the first half of July.

Squash bug (*Anasa tristis* DeG.) which was more abundant in 1931, than for many years, again overwintered in large numbers and during August and September it was a general pest in all parts of the state, attacking squash and pumpkin. Sazama reports that this insect was abundant and that it practically prevented growing any squash or pumpkins in the vicinity of Vincennes and that it was exceedingly troublesome in homes. The same situation occurred at Bedford, according to

Marshall. In many of the collections the southern leaf-footed plant bug (*Leptoglossus oppositus* Say) occurred in almost equal numbers as the common squash bug.

Squash vine borer (*Mellitia satyriniformis* Hbn.) injured squash and pumpkin in all parts of the state during July and into August. At Lafayette their abundance, combined with effects of dry weather in July, caused the death of many squash plants.

Mexican bean beetle (*Epilachna corrupta* Muls.) extended its range of destructiveness to practically all sections of Indiana during 1932, reports having been received from every county except Newton, Lake and Porter in the northwestern corner. The favorable winter of 1930-31 enabled this insect to be destructive in a few localities in northern Indiana in 1931. The second mild winter (1931-32) apparently enabled large numbers to winter over successfully farther north than ever before and as a result we were besieged with inquiries. The first report was received May 28, but most inquiries were received after June 6, being very abundant during July. Also many inquiries in August. A new generation commenced to appear at Lafayette about August 17, and by August 26 had destroyed many bean patches. The potato beetle killer (*Perillus bioculatus*) was reported from several points in Southern Indiana, where it was observed feeding on larvae of the Mexican bean beetle and the Colorado potato beetle.

Onion thrips (*Thrips tabaci* Lind.) began to show up in threatening numbers in the onion fields of Northern Indiana early in June. However, serious damage did not develop.

Wooly bear caterpillars (probably *Diacrisia virginica* Fab.) were abundant on onion at Columbus, according to a report received June 15.

Egg plant flea beetle (*Epitrix fuscula* Crotch) was observed as very destructive to young egg plants at Lafayette, June 10. A new generation of adult beetles were appearing July 16, and by July 22 most untreated plants were practically defoliated. Reports received show that it was generally abundant and destructive throughout the state. Excellent control was obtained with Bordeaux as a spray and barium fluosilicate as a dust.

Colorado potato beetle (*Leptinotarsa decemlineata* Say) were attacking potato at Indianapolis in May as soon as the plants appeared above ground. Later in the season they were normally abundant throughout the state. The potato beetle killer (*Perillus bioculatus*) was reported abundant and effective in checking the abundance of these pests in several localities.

Potato leafhopper (*Empoasca fabae* Harr.) was only moderately abundant in the potato growing areas.

Aphis rumicis L. reported destructive to cultivated dock at Brookston, June 13.

Rhubarb curculio (*Lixus concavus* Say) damaged rhubarb at Fort Wayne, June 10.

Tortoise beetles (*Chrysomelidae*) were reported severely damaging sweet potatoes at Vincennes, July 2.

Wireworms (*Elateridae*) damaged tomatoes at Ladoga, May 31.

Pale striped flea beetle (*Systema taeniata*, var. *blanda* Melsh.) dam-

aged tomato at Kokomo, June 13, sweet corn at Plymouth, June 25, and crops not reported at Albion, June 21.

Blister beetles were probably normally abundant throughout the state, especially in the northern half of the state. Three species were involved, namely, *Epicauta vitatta* Fab., *E. marginata* Fab. and *E. pennsylvanica* DeG. The first reports were received July 7, and continued through August, in fact a few reports were received up to September 15. Quite a variety of plants were reported as damaged, but potatoes, tomatoes, and beets were the most common hosts. Marshall states that blister beetles were more abundant and destructive in the vicinity of Bedford than in 1931.

Cutworms *(Noctuidae)* were reported destructive to such crops as corn, beans, cabbage, sweet potato, and hollyhock during May from many localities in the northern half of the state.

Garden slugs *(Helix* sp.) were abundant under debris at Frankfort, May 7, in a locality where they were destructive in gardens in 1931. They were also annoying in basements in several localities of central Indiana this fall; also, in hotbeds.

Millipedes have been reported from year to year but apparently they are incidental with other trouble in most cases. However, in 1931, and again in 1932, they were definitely destructive to potatoes in the muck areas of Northern Indiana. In one case mint damage was reported but as in several other cases of injury, we were unable to visit the region and absolutely verify the report. The first of June we had one report which was probably authentic, reporting that millipedes were playing havoc in a bottom land field of corn at Bloomfield.

The mint flea beetle (*Longitarsus waterhousei* Kutsch) continues as a serious pest of mint in northern Indiana, which is almost certain to be a permanent hindering factor in mint production. At Warsaw, the first pupae were found June 23, and the first adults appeared July 8, which is several days later than for the previous two years.

FRUIT INSECTS

Codling moth larvae *(Carpocapsa pomonella* L.) wintered over in large numbers with a low winter mortality and the early prospects were for an abundance of worms, which proved to be the case. On April 23, three per cent of the over-wintering worms had pupated at Bedford, while none had pupated at Lafayette on that date. The first adults from over-wintering worms appeared at Bedford, May 6, and the first eggs noted May 9, but because of the cool weather following they did not hatch until May 22. At Lafayette the first moths did not appear until May 20. At Bedford the first larvae left the apples 23 days after hatching, that is June 14, and the second brood adults issued 15 days later on June 29. An early adult of this brood emerged at the Troth-Burton Orchard at Mitchell, June 21. The first larvae of the second brood hatched July 8, and on Aug. 2, these larvae were leaving apples to pupate. The adults of this second brood of worms began to issue Aug. 17, and they were laying eggs on Aug. 23. These eggs hatched Aug. 31 and before cold weather had left the apples to build hibernaculae

for over-wintering. The past year has been one of the worst codling moth seasons, if not the worst, for perhaps six years. The worms are abundant in winter quarters and will require extra efforts in 1933 to prevent more serious damage.

Apple leaf skeletonizer *(Psorosina hammondi* Ril.) defoliated young, unsprayed apple trees in a few cases near Bedford, but in well-kept orchards it was not a problem.

Red humped caterpillar *(Schizura concinna* S. and A.) was abundant on apple at New Albany and Franklin the middle of July. Other common caterpillars in southern Indiana, especially in young, unsprayed orchards were the yellow-necked apple caterpillar *(Datana ministra* Drury), white-marked tussock moth caterpillar *(Hemerocampa leucostigma* S. & A.), webworms *(Hyphantria cunea* Drury), and "canker worms."

Apple curculio *(Anthonomus quadrigibbis* Say) was abundant and destructive to apple at Lafayette.

Apple leafhoppers were abundant early in April but did not show the increase anticipated, in fact they did little if any injury.

Apple aphids *(Aphis pomi* DeG. and *Rhopalosiphum prunifoliae* Fitch) were abundant on apple in the green bud stage, but gradually decreased until April 25, when they became quite scarce.

Rosy apple aphid *(Anuraphis roseus* Baker) was abundant on apple in several regions of central and southern Indiana early in June and their persistence in some orchards resulted in injury to fruit. By late June these aphids were well under control as a result of the activity of natural enemies.

Wooly apple aphid *(Eriosoma lanigerum* Haus.) was abundant at Lafayette early in July.

Apple scurfy scale *(Chionaspis furfura* Fitch) was abundant and destructive to apple at Brookville and Lebanon. At Bedford it was more abundant late in the season than for at least three years.

San Jose scale *(Aspidiotus perniciosus* Comst.) wintered over very successfully and was abundant and destructive where thorough control measures were not applied. In most cases, however, the commercial growers adopted the controls stressed by the entomologists, resulting in very effective control. A severe infestation in an old orchard at Bedford was almost completely destroyed by a fungous disease during July and early August.

Round-headed apple tree borer *(Saperda candida* Fab.) damaged apple trees at Lafayette during September.

Pear-leaf blister mite *(Eriophyes pyri* Pagen.) was abundant on pear at Marion, August 4.

Pigeon tremex *(Tremex columba* L.) was observed as very common ovipositing in pear trees at Nappanee, September 28.

Oriental fruit worm *(Laspeyresia molesta* Busck) wintered over in large numbers, but the severe March weather killed about 90 per cent or more of the peach buds in Southern Indiana, which was unfavorable to this peach pest. Twig injury gradually increased until July 25, when the injury was severe, but after that date there was a decrease. There was a progressive increase in the numbers of moths caught in bait traps

from the first to 16th of August. In the Vincennes area Krummel peaches were very heavily infested and from 1 to 43 per cent of all the larvae in apples were this species. Sazama reports heaviest overwintering population in years. In spite of very unfavorable conditions for this pest it is wintering over in rather large numbers.

Cat-facing, caused by tarnished plant bug (*Lygus prataensis* L.), was severe for the few peaches that developed.

Plum curculio (*Conotrachelus nenuphar* Herbst) was reported abundant from several localities in the state. At Lafayette the first adults were jarred from trees May 1. In general, it was probably more destructive to apple, peach and cherry than in 1931.

Shot hole borer (*Scolytus rugulosus* Ratz.) was reported damaging cherry and plum from a number of localities. At Shelbyville on August 29, the adult beetles were injuring cherry leaf buds.

Tree crickets (*Oecanthus nigricornis* Walk.) were reported from several localities in Northern Indiana, where they were ovipositing in raspberry canes.

Rose scale (*Aulacaspis rosae* Bouche) was abundant on rose at Lafayette and raspberry at Terre Haute.

Grape filbert gall (*Schizomyzia coryloides* W. & R.) was received from Frankfort, August 1.

Strawberry leaf roller (*Ancylis comptana* Froh.) was abundant generally in Northern Indiana, reports coming in from May 24 to August 2. Not especially abundant in Southern Indiana, according to reports excepting in the vicinity of Princeton where it was quite destructive.

Strawberry rootworm (*Paria canella* Fab.) was destructive to strawberry at Aurora, according to a report received October 4.

Strawberry crown borer (*Tyloderma fragariae* Ril.) was reported from several localities in the northeastern part of the state and also from the western part.

Root knot nematode (*Heterodera radicicola* Greef) on strawberry was reported from two localities according to Ulman.

The 17-year cicada (*Cicada septendecim* L.) was authentically reported from Ashley and Bedford the first half of June. However, no injury was reported.

SHADE TREE AND SHRUB INSECTS

Bagworms (*Thyridopteryx ephemeraeformis* Haw.) was reported from Kingman, Lebanon, Crawfordsville, Indianapolis, Evansville, Sullivan and other points in Southern Indiana, the reports coming in throughout the season. Besides reports of abundance on apple they were observed on cedar, boxelder, maple, arbor vitae, cottonwood and blue spruce. Recently hatched larvae were abundant on young apple trees at Crawfordsville, June 6.

Catalpa sphinx caterpillars (*Ceratomia catalpae* Boisd.) were abundant and defoliating catalpa trees in many localities in the northern half of the state, as well as in Southern Indiana, during June and July. The second generation of worms began to appear at Lafayette, August 14, and at points farther north a few days later. A disease was responsible for killing many of the fall brood of worms in Southern Indiana.

Walnut caterpillars (*Datana integerrima* G. and R.) were very abundant in the southern half of Indiana. One correspondent reported that nearly all of the walnut trees in the southern third of the state were defoliated by July 18. Sazama states that not a single walnut, hickory or pecan within 100 miles of Vincennes escaped defoliation and that some walnut trees put out three sets of foliage.

Bronze birch borer (*Agrilus anxius* Gory) was reported as destroying cut-leaf birch at Seymour, June 29.

Ash borer (*Podosesia fraxini* Lug.) was abundant in ash at Muncie and Anderson. Adults were issuing at Anderson, May 21.

Locust borer (*Cyllene robiniae* Forst.) seriously damaged black locust at Gary, according to a report received June 28.

Flat-headed borer (*Chrysobothris femorata* Oliv.) was reported damaging maple at Kurtz, Delphi, Michigan City, Frankfort and Hagerstown and destructive to apple at Marshall.

Lilac borer (*Podosesia syringae* Harr.) was abundant on lilac at Fowler.

Oyster shell scale (*Lepidosaphes ulmi* L.) was reported abundant on lilac at Alexandria, Greenfield, Kendallville, Knightstown, Lafayette, Richmond, Terre Haute, Waynetown, Wheatfield, and Williamsport and on ash at Williamsport and Wheatfield.

Cottony maple scale (*Pulvinaria vitis* L.) abundant at Gary, Lizton, Marion, Peru, Portland and Shipshewana.

Pine leaf scale (*Chionaspis pinifoliae* Fitch) was abundant on blue spruce at Milroy and Madison, pine at Kendallville, and juniper at Aurora.

Tulip tree scale (*Toumeyella liriodendri* Gmel.) was abundant on magnolia at Pekin and on tulip tree at Eminence, Lafayette and Peru. The last locality is the most northern record we have ever had for this species.

Spiraea aphid (*Aphis spiraecola* Patch) was normally abundant on *Spiraea van houttei* throughout the northern half of the state.

Snowball aphid (*Anuraphis viburnicola* Gill.) was normally abundant at Lafayette and Knightstown and probably elsewhere throughout the state.

Linden aphid (*Longistigma longistigma* Wils.) was reported very abundant on linden at South Bend, October 24.

Common willow aphid (*Melanoxantherium smithae* Monl.) reported as very abundant on willow at Richmond and Madison early in October.

Boxelder bug (*Leptocoris trivittatus* Say) has been the subject of a great many inquiries, some because of their abundance and damage to boxelder trees but more often because of their annoyance in homes. Last winter and spring these insects, which had sought shelter in homes to pass the winter the previous fall, became quite active because of the mild winter. This past fall we received more inquiries than ever before and evidently they were more abundant and widespread than for many years. The first reports came the latter part of June when they were observed very abundant on boxelder trees. Later they were reported because of their persistence in entering homes and these inquiries continued up until cold weather. Reports of abundance were received from

practically every county north of Indianapolis, and from only two counties south of the center of the state, namely, Sullivan and Lawrence. One report of injury to strawberry plants was received but not verified.

Red Spider *(Tetranychus telarius* L.) was normally abundant out-of-doors. Reports of notable damage were received from Aurora, Anderson, Bedford, Clinton, Jamestown, Lafayette, Linden, Marion, Shelbyville, Sidney and Thorntown and the plants reported attacked included ornamental juniper shrubs, arbor vitae, cedar, spruce, hard maple, soft maple, raspberry, phlox and dahlia. Most of the inquiries were received the latter half of June and about the middle of July.

Elm cockscomb gall aphid *(Colopha ulmicola* Monl.) was reported as quite abundant on elm from many localities in the northern half of the state.

Flower Garden, Greenhouse and Lawn Insects

Io moth caterpillars *(Automeris io* Fab.) reported attacking gladoli at Milton, August 1.

Gladiolus thrips *(Taeniothrips gladioli* M. and S.), a new pest of gladiolus appeared in the state and was a pest in several localities, including two places in Dekalb County and one in each of the counties of Allen, Elkhart, Carroll and Marion. In Carroll County, near Delphi, it caused considerable loss, the insect apparently being introduced on bulbs purchased in one of the eastern states this past spring. The infestation was very heavy and resulted in almost complete loss of flowers in at least two of the other localities referred to.

Onion thrips *(Thrips tabaci* Lind.) damaged pompons and cyclamen at New Albany early in January.

Chrysanthemum lace bug (*Corythuca marmorata* Uhl.) was abundant on chrysanthemum out-of-doors at Lafayette during August.

Mexican mealy bug *(Phenococcus gossypii* T. and C.) has in the past few years become one of the most serious of all greenhouse pests, being especially destructive to chrysanthemum. On October 19, John Amos, a graduate student at Purdue, found it common on the following plants out-of-doors at Lafayette: *Amarantus* sp. border or fountain grass *(Rennisetum ruppelii), Canna* sp., egg plant *(Solanum melongena), Lantana* sp., and flowering sage *(Salvia* sp.).

The common greenhouse mealy bug *(Pseudococcus citri* Risso) was reported common on house fern at Logansport, house plants at Lake Cicott, *Asparagus sprengeri* at Anderson, cactus at Terre Haute, and Coleus at Bedford, Elwood and Hammond.

Phlox plant bug *(Lopidea davisi* Knight) was a serious pest of perennial phlox at Bloomington and Columbus the last of August and early in September.

Fern scale *(Hemichionaspis aspidistrae* Sign.) was commonly reported as abundant on house ferns from many localities.

Hemispherical scale *(Saissetia hemisphaerica* Targ.) was occasionally reported infesting house fern.

The soft scale *(Coccus hesperidum* L.) was abundant and destructive to begonia at Fairmount.

A camel cricket *(Tachycines asynamorus* Adelung, Caudell det.) was reported damaging flowering greenhouse plants at Indianapolis early in November.

Rose beetle *(Macrodactylus subspinosus* Fab.) was reported very abundant from June 9-23 in a number of northern Indiana localities, including Claypool, Crown Point, Denver, LaPorte, Michigan City, Peru and Warsaw. The crops attacked included all kinds of garden plants, those specifically referred to being rose, peony, strawberry and grape. At Peru they were responsible for the death of many chickens and at Claypool for the death of young ducks.

Rose slug *(Cladius isomerus* Nort.) injured rose at Albion, Henderson and Lafayette early in July.

Large green rose aphid *(Macrosiphum rosae* L.) was a pest of rose about the middle of June at Franklin, Gary, Griffith and Rome City.

The pea aphid *(Macrosiphum pisi* Kalt.) was abundant on sweet pea at Gary early in June.

Silver spotted skipper *(Epargyreus tityrus* Fab.) reported common on wisteria at Muncie, July 5.

Fungus gnat maggots *(Sciara* sp.) were reported several times early in the spring as abundant in soil of potted plants. In most cases the reports originated because of an abundance of the adult flies.

Sowbugs were reported abundant in greenhouses from several localities. At New Albany they were definitely reported attacking seedling petunias; at Brazil potted plants; at Portland, mushrooms and defoliating flowering plants; at Anderson pansy plants; and at Fort Wayne, "flowering plants", while at Anderson they were reported as annoying in the basement.

Webworms *(Crambidae)* damaged golf greens at Franklin and Greencastle the middle of June. However, they were not generally or severely damaging as the previous two seasons.

The grubs of the green June beetle (*Cotinus nitida* L.) were abundant and destructive in lawns at Evansville, September 23.

Cutworms (chiefly *Agrotis ypsilon* Rott.) were responsible for material damage to golf greens at Lafayette and probably elsewhere in the state. Experiments by Packard indicated proper application of arsenate of lead, kerosene emulsion or pyrethrum extracts to be effective control measures.

PESTS OF STORED PRODUCTS

Grain weevils and grain beetles of various kinds have been more prevalent and destructive than for many years, due no doubt to the fact that much old grain has been held over. As early as last June reports were received from central and southern Indiana of infestations in old grain. During July the inquiries became more frequent. The cadelle *(Tenebroides mauritanicus* L.) appeared to be the chief offender, although the confused flour beetle *(Tribolium confusum* Duval), saw-toothed grain beetle *(Oryzaephilus surinamensis* L.) and true grain weevils *(Sitophilus* sp.) were numerous in grain and stored products such as flour and meal. The cigarette beetle *(Lasioderma serricorne* Fab.)

and cadelle were heavily infesting a patent dairy feed according to one report.

The Angoumois grain moth (*Sitotroga cerealella* Oliv.) was more abundant than for many years in the southern half of the state, the most severe infestation occurring in the general vicinity of Vincennes where much of the corn in the field was infested before harvest. A report last winter from Decatur showed oats in the bin infested, the upper three or four inches showing a heavy infestation.

A great many reports were received from every section of the state, relative to bean weevils (especially *Mylabris obtectus* Say). It was apparently more abundant than for a number of years.

Buffalo beetle (*Anthrenus scrophulariae* L.) was reported from Anderson, Elkhart, Fort Wayne, Indianapolis, Logansport and Mishawaka.

Black carpet beetle (*Attagenus piceus* Oliv.) was destructive to clothing and carpet at Columbus, Elkhart, Fairbanks, Kendallville, Logansport, Oaktown and Walkerton.

Clothes moth (*Tinea pellionella* L.) damaged overstuffed furniture at Avon, Clinton and New Paris and woolen goods at Lafayette and Wolcottville.

Cigarette beetle (*Lasioderma serricorne* Fab.) reported as infesting furniture at Seymour.

Drug store beetles (*Sitodrepa panicea* L.) were reported breeding abundantly in a dog food and in dry mustard.

Silverfish (*Lepisma saccharina* L.) reported annoying and destructive at Bourbon, Elkhart, Kendallville, Kokomo, Lafayette, Marion, South Bend and Terre Haute. In one case they damaged curtains.

Termites (*Reticulitermes flavipes* Koll.) were reported as very destructive from every section of the state and were at least normally abundant. The first reports were received during April when winged sexual forms began to make their appearance. Aside from damage to buildings, these insects damaged geranium plants in one instance by tunnelling the stems and in another case tunnelled through stacks of stored printing paper causing a considerable loss.

Larvae of *Eburia quadrigeminata* were reported working in floors of a house at Parker in July.

Powder post beetles (*Lyctus* sp. and possibly others) have been destructive in all parts of the state, attacking old hickory furniture, timber in farm buildings and homes, lumber in commercial yards and implement handles.

A carpenter bee (*Xylocapa virginica* L., Sandhouse det.) was quite annoying tunnelling in wood of a log cabin at Lake Maxinkuckee.

ANNOYING AND MISCELLANEOUS PESTS

Bedbugs (*Cimex lectularius* L.) was reported as a household pest from many localities, probably more than usual. In one case at Huntingburg, they were pests in poultry houses.

Cockroaches (*Blattella germanica* L., *Blatta orientalis* L. and *Periplaneta americana* L.) were reported from many places in the state.

Clover mites (*Bryobia praetiosa* Koch) were annoying in a home at Pekin, April 15.

The usual number of inquiries were received regarding abundance of ants in homes and in lawns, every section of the state being represented.

Field crickets *(Gryllidae)* were annoying in basements at Hammond in August.

Mosquitoes were normally abundant in all sections of the state.

Fleas *(Ctenocephalus canis* Curt.) were normally abundant in homes and barns throughout the state.

Booklice *(Atropes* sp.) were irritating in bedding and elsewhere in a home at Evansville and Kouts during September.

Chiggers *(Trombicula irritans* Ril.) were abundant in lawns and elsewhere at various places, definite reports from Fishers, Lafayette and Richmond coming in during June and July.

Bloodworms *(Chironomidae)* were abundant in a well at Columbus in March.

Horse bot flies *(Gastrophilus,* probably *intestinalis* DeG.) were so annoying in parts of Tippecanoe County the first week in July that it was almost impossible to work horses.

Poultry feather mite (*Liponyssus* sp.) was abundant at Stilesville in May.

Poultry lice (*Mallophaga*) were common in some sections, but probably not as abundant as usual, judging from inquiries received.

Body lice were reported abundant on goats at Warsaw in January.

Hog lice *(Haematopinus suis* L.) was not reported frequently, although generally common throughout the state.

THE CICADELLINAE OF INDIANA (CICADELLIDAE, HOMOPTERA)

HOWARD O. DEAY, Purdue University[1]

The insects composing the family Cicadellidae are commonly called leafhoppers. They are all distinctly plant feeders and since there are so many species of them, most of which contain thousands of individuals, they damage growing crops considerably. Indeed some of them, as the potato leafhopper, do such severe injury that they are the limiting factor in the profitable production of the crop they attack.

The family may be characterized as follows: antennae minute, bristle-like, inserted in front of and between the compound eyes; hind tarsi three-segmented; two ocelli or none; pronotum normal, not prolonged over the abdomen; and the hind tibiae armed with a double row of spines throughout their length.

The leafhopper occurring in Indiana includes five distinct subfamilies which may be separated as follows:

KEY TO SUBFAMILIES OF INDIANA CICADELLIDAE

1. Veins of fore-wings branch near base, then extend without branching to cross veins which form the apical cells; no anteapical cells present. Ocelli usually wanting or inconspicuous—Typhlocybinae.

1′. Veins of fore-wings branching on the disc; anteapical as well as apical cells usually present. Ocelli, present.....2.

2 (1′) Ocelli on front below margin of vertex.....Bythoscopinae

2′(1′) Ocelli not on front, either on border between the vertex and front or on the vertex.....3.

3 (2′) Ocelli on margin of vertex, or between the vertex and front .....Jassinae

3′(2′) Ocelli on disc of vertex, usually distant from its margin...4

4 (3′) Body robust, depressed or flattened.....Gyponinae

4′(3′) Body cylindrical, not depressed or flattened....Cicadellinae

SUBFAMILY CICADELLINAE VAN DUZEE

The subfamily Cicadellinae contains those leafhoppers which have the ocelli located on the disc of the vertex and the body elongate and cylindrical. Each antenna arises from a rather deep cavity which is overhung by a more or less prominent ledge formed by the margin of the vertex. The species are usually large, in fact some of the largest of our leafhoppers belong here.

[1] This is the first of a series of papers on the leafhopper fauna of Indiana. The writer wishes to express his appreciation to Dr. R. W. Sampson for assisting him in making the photographs herein included.

Van Duzee (5)* lists 12 genera, 48 species and 10 varieties of this subfamily that occur in America north of Mexico. Some half dozen species have been added to the list since Van Duzee's catalogue was published. But two of the species *(Cicadella occatoria* and *Kolla bifida* Say) of this subfamily have been recorded as occurring in Indiana although some of the others have been reported from the neighboring states. Van Duzee (5) ignores Say's (4) record that the two above mentioned species were described from Indiana.

Although no extensive or intensive collections have been made of the Cicadellinae in Indiana, the writer has examined specimens of nine genera, 13 species and one variety of the subfamily which have been taken in the state. He has seen no specimens of *C. occatoria* which have been taken in Indiana. Five other species, *Draeculacephala novebora-censis* (Fitch), *D. inscripta* (Van Duzee), *D. minor* (Walker), *D. angulifera* (Walker) and *Kolla geometrica* (Signoret) in all probability occur here.

The county has been chosen as the collection unit. Although some species have been taken only in one or two counties, they doubtless occur in others and the writer plans to publish other collection records as they come to his attention. The plants from which the specimens were captured are given when known. However, these plants may not be the true hosts, for as Ball (2) points out, the true host may be an entirely different plant from the one on which the insect is taken.

The various collectors of the material examined are indicated after the dates of capture by their initials. These collectors and their initials are as follows: J. M. A.—J. M. Amos; H. L. C.—H. L. Cook; J. J. D.—J. J. Davis; H. O. D.—H. O. Deay; G. E. G.—G. E. Gould; R. R. H.—R. R. Heaton; W. D. M.—W. D. Miller; B. E. M.—B. E. Montgomery; L. I. M.—L. I. Musgrave; P. S. C.—all specimens collected by the students in the various entomological classes at Purdue University and deposited in the student collection are indicated by the initials P. S. C. Most of these specimens have been taken in Tippecanoe County, but a goodly number have been taken in Clark County at the Forestry camp. H. K. R.—H. K. Riley; L. B. S.—L. B. Steiner; F. H. T.—F. H. Test; and A. W. T.—A. W. Trippel

The nomenclature used is that of Van Duzee (5)

Representatives of all the species that have been taken in Indiana are deposited in the Purdue Entomoligical collection.

KEY TO THE INDIANA GENERA OF CICADELLINAE

1. Ocelli near front margin of vertex.....*Evacanthus.*

1'. Ocelli near center of certex.....2.

2 (1'). Fore-wings not covering lateral margins of abdominal segments. Antennal sockets overhung by a distinct ledge. Head and pronotum deflexed.....3.

2'(1'). Fore-wings covering lateral margins of abdominal segments. Ledge on margin of vertex above antennal sockets small, not projecting beyond curve of head. Head and pronotum not deflexed.....4.

* Numbers in parentheses refer to papers listed in references cited.

3 (2). Pronotum roundingly six-angular, posterior margin rounding with a slight median excavation. Vertex longitudinally furrowed. ..... *Aulacizes.*

3′(2). Pronotum four angular, anterior and posterior margins nearly parallel. Vertex not longitudinally furrowed..... *Oncometopia.*

4 (2′). Fore-wings reticulately veined, at least on apical third. Head triangularly produced, often longer than pronotum..... ..... *Draeculacephala.*

4′(2′). Fore-wings not reticulately veined on apical third. Head not greatly produced..... 5.

5 (4′). Scutellum less than half as long as pronotum..... ..... *Helochara.*

5′(4′). Scutellum more than half as long as pronotum..... 6.

6 (5′). Vertex flat, margin distinct, acutely angled with the front. ..... *Graphocephala.*

6′(5′). Vertex margin rounded, front inflated..... 7.

7 (6′). Lateral margins of vertex somewhat rounded not in a definite line with the outer margins of the compound eyes..... *Cicadella.*

7′(6′). Lateral margins of vertex in a continuous line with the outer margins of the compound eyes..... 8.

8 (7′). Vertex short and blunt, twice as wide as long, half as long as pronotum. ..... *Kolla.*

8′(7′). Vertex longer and more pointed, only about 1¼ times as wide as long, as long as pronotum..... *Pagaronia.*

GENUS ONCOMETOPIA STOL

The members of this genus have large eyes which make the head wider than the pronotum. The margins of the vertex form distinct ledges over the antennal sockets. The pronotum is comparatively short, four angled; the anterior margin is concavely arcuate, the posterior margin is emarginate and nearly parallel to the anterior. The fore-wings are longer than the abdomen but narrower, the lateral margins of the abdominal terga being exposed.

But two species of this genus are found in the United States, both of which occur in Indiana.

KEY TO SPECIES

1. Vertex black, irrorate with yellow. Not over 8 mm. long. ..... *lateralis.*

1′. Vertex rusty orange with black markings. Over 12mm. long. ..... *undata.*

Oncometopia undata (Fabr.)

Fabricius, J. C. Entomologia Systematics 4 : p. 32. 1794, *Cicada.*

These are large, parallel-sided leafhoppers. Length to tip of fore-wings, 13 mm.

The front is orange yellow with black median and lateral lines. The vertex rusty orange with an irregular black circle on disc from which radiates 6 or 8 black lines. Anterior portion of pronotum orange

yellow, posterior portion varying in color from slatey blue to brown or red. The scutellum is orange yellow marked with dark lines. The color of the fore-wings varies from slaty blue to brown or red.

The last ventral segment of the female is longer than the preceding, slightly narrowed posteriorly; the posterior margin 3 lobed, the lateral ones distinctly longer than the median. The plates of male form a triangle which is about as long as wide; the pygofers are nearly twice the length of the plates and bear an upturned chitinous process on the posterior margin.

COLLECTION DATA

Knox Co., Aug. 8, Sept. 20 (B.E.M.); Lawrence Co., July 16 (L.F.S.); Aug. 16, 21 on mulberry (L.I.M.); Porter Co., Sept. 2 (B.E.M.); Tippecanoe Co., May 4, 16, 24 on grape, Sept. 19 (P.S.C.); July 20 on willow (A.W.T.).

Oncometopia lateralis (Fabr.) (Fig. 1)

Fabricius, J. C. Entomologia Systematics, Suppl. p. 524, 1798, *Cercopis.*

Robust insects shorter than *undata.* Length to tip of fore-wings, 7-8 mm.

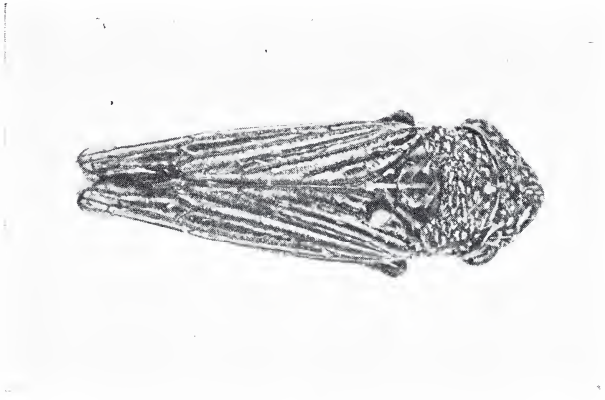


Fig. 1. *Oncometopia lateralis* (Fabr.), X 6½.

Front, vertex, pronotum and scutellum are black irrorate with yellow. The fore-wings reddish to slaty blue with the veins and linear areas black, frequently with light or yellow margins. A narrow lateral yellow stripe extends from each eye across the thorax and along the margin of abdomen to the pygofers.

The last ventral segment of the female is about twice as long as the preceding; the posterior margin has a broad median incision which reaches about one-fourth of the way to the base. The plates of the male form a triangle which is longer than wide; the pygofers are long and narrow, exceeding the plates.

Collection data:

Clark Co., July 31 on grass and sumac (P. S. C.). Tippecanoe Co., Oct. 13 on turnips (P. S. C.).

The variety *limbata* (Say), which differs from above in having the fore-wings shining black has not been observed in Indiana by the writer.

Genus *Aulacizes* Amyot and Serville

In this genus the margins of the vertex form distinct ledges over the antennal sockets. The vertex is moderately produced with its apex bluntly rounded and with a distinct median furrow. The pronotum is roundingly 6-angled with the posterior margin slightly emarginate. The fore-wings are longer than abdomen; narrow, not covering lateral margins of the terga.

One of the two species which have been recorded from the United States occurs in Indiana.

Fig. 2. *Aulacizes irrorata* (Fabr.), X 6½.

Aulacizes irrorata (Fabr.) (Fig. 2)

Fabricius, J. C. Entomologia Systematics 4: p. 33. 1794, *Cicada.*

The members of this species are large, elonate cylindrical insects. Length to apex of fore-wings, 11-12.5 mm.

The general color varies from light to reddish brown, irrorate with yellow, and with black splotches on vertex and scutellum. The front irrigularly black below, yellow above with 4 black spots. Costal margins of fore-wings yellow. Abdomen red above, yellow below.

Head is a little wider than pronotum; vertex has a deep median longitudinal furrow and one next each ocellus. Surface of vertex coarse and pronotum coarsely pitted. Last ventral segment of the female about as long as preceding, much narrowed caudally; posterior margin broadly rounded to a shallow median notch. Valve of male very small, nearly

hidden by last ventral segment; plates form a triangle which is a little broader than long; the pygofers short and broad about equal to the plates in length.

Collection data:

Clark Co., June 28 (P. S. C.); Morgan Co., July 14, Aug. 7, Oct. 21 (L. I. M.); Parke Co., Sept. 11 (G. E. G.); Ripley Co., Oct. 15 on walnut (H. O. D.); Tippecanoe Co., May 3, 13, Sept. 20, Nov. 21 (P. S. C.), Sept. 26 on willow (R. R. H.), Oct. 8 on willow (A. W. T., H. O. D.), on maple (W. D. M.); Warren Co., Oct. 12 on grass (P. S. C.).

GENUS *Cicadella* Latreille

In this genus the head is bluntly conical; the lateral margins of the vertex do not form a continuous curve with the curve of the eyes; the eyes and ledge over the antennal sockets are not prominent. Pronotum is less than twice as long as the scutellum. The fore-wings are longer than the abdomen and cover the lateral margins of the abdominal terga; venation simple, not reticulate.

The writer has seen two species and one variety of this genus that have been taken in Indiana. Say (4) in his original description of *occatoria* states that it "inhabits Indiana" as well as Florida and Louisiana.

KEY TO THE INDIANA SPECIES OF CICADELLA

1. Vertex as long as wide, head narrower than pronotum ..... *occatoria.*

1′. Vertex wider than long, head wider than pronotum.....2.

2 (1′). Head pattern complex, transversely marked; no straight longitudinal median lines.....*hieroglyhica.*

2′(1′). Head pattern simple, made of longitudinal stripes..*gothica.*

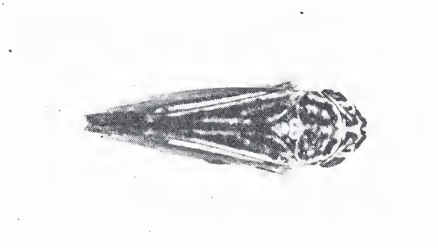


Fig. 3. *Cicadella hieroglyphica* (Say), X 6½.

Cicadella hieroglyphica (Say). (Fig. 3)

Say, Thomas, Jour. Acad. Nat. Sci. Phila. 6: p. 313, 1831, *Tettigonia.*

Rather stout, medium sized, reddish insects. Length to apex of fore-wings, 6-7 mm.

The general color varies from a brick red to greenish and slaty blue. Vertex with a black spot at apex, encircled by whitish yellow; the rest

of vertex ornamented with distinct black markings which enclose a light colored T on the basal half. Pronotum light anteriorly, posteriorly brownish marked with light. Central portion of scutellum yellowish. Veins of fore-wings dark; pale bands along costal, claval and sutural margins.

Posterior margin of pronotum shallowly emarginated. Last ventral segment of female less than 3 times longer than preceding; posterior margin triangularly produced, apex rounded. Last ventral segment of the male less than twice as wide as long; plates long and tapering to acute apices.

Collection data:

Decatur Co., Oct. 15 on willow (H. O. D.); Jennings Co., Oct. 15 sweeping weeds and shrubs along stream (H. O. D.); Johnson Co., Oct. 15 (H. O. D.); Marion Co., Oct. 15 sweeping roadside weeds (G. E. G., H. O. D.); Morgan Co., Oct. 3 on clover (L. I. M.); Tippecanoe Co., Sept. 25 on grass, Sept. 26, Oct. 21 (P. S. C.); Sept. 26 on willow (R. R. H.); Oct. 8 on lamb's quarter (A. W. T.), Oct. 25 on willow (H. O. D.).

Cicadella hieroglyphica var. *dolobrata* (Ball)

Ball, E. E. *Proc. Ia. Aca. Sci.* 8: p. 18. 1901, *Tettigonia.*

The male of this variety is smaller than typical *hieroglyphica.* The color is typically black, but a few of the light markings of *hieroglyphica* are retained on the front, vertex, pronotum and scutellum, and generally the claval sutures are light.

The females are more like typical *hieroglyphica* except the black markings on the head are not so prominent and the general color is slaty gray.

Lawson (3) points out that this variety is really the summer generation of typical *hieroglyphica* which produce the overwintering "reddish" generation. The Indiana collecting dates bear out this contention.

Collecting data:

Clark Co., July 1 (P. S. C.); Morgan Co., July 13 on weeds along river (R. R. H.); Tippecanoe Co., July 23 on willow (H. O. D.).

Cicadella gothica (Sign.) (Fig. 4)

Signoret, V. Ann. Soc. Ent. Fr. ser. 3. 2: p. 354, 1854, *Tettigonia.*

This species has much the same form as *hieroghyphica* but is smaller. Length to the tip of fore-wings, 5.5-6 mm.

The general color varies from light reddish to grayish green with dark mottlings. The markings on the vertex is in the form of parallel longitudinal lines on the disc and simple outer lines. The scutellum has distinct black marks.

The posterior margin of the pronotum is truncate. The last ventral segment of the female is three times longer than the preceding segment; posterior margins triangularly produced. Last ventral segment of the male about twice as wide as long; plates very long and slender.

Collection data:

Harrison Co., Aug. 30 (J. J. D.); Morgan Co., Oct. 21 (L. I. M.); Parke Co., July 26 on *Eupatorium urticaefolium* (F. H. T.); Porter Co., Aug. 6 (J. J. D.); Tippecanoe Co., July 22 (G. E. G.).

Fig. 4. *Cicadella gothica* (Sign.), X 6½.

Cicadella occatoria (Say)

Say, Thomas. *Jour. Acad. Nat. Sci. Phila.* 6: p. 311. 1831. *Tettigonia.*

This is a slender species. Length to tip of fore-wings, 6 mm.

The general color is yellow striped with brownish black lines above. The vertex has four longitudinal brownish black lines, the pronotum five, and each fore-wing about six.

The last ventral segment of the female is scarcely twice the length of the preceding, posterior margin obtusely rounded. Male plates broad, triangular, much shorter than pygofers.

Say, in his original description, records this species from Indiana. The writer has seen no specimens of this species and there is no record that it has been taken in Indiana since Say's time.

Genus Kolla Distant

In this genus the vertex is short and blunt, but half as long as pronotum and twice as wide as long, narrowed subconically apically, and with the lateral margins in a continuous line with the curve of the compound eyes. The eyes and the ledge over the antennal sockets are not prominent. The pronotum is less than twice as long as the scutellum. The fore-wings cover the lateral margins of the abdominal terga, the venation is simple.

Two species of this genus have been collected in Indiana and a third, *geometrica* (Signoret), doubtless occurs in the southern part of the state as it has been taken in Ohio, Illinois and Kentucky. It may be distinguished from the two species known to occur here by the characters given in the key.

KEY TO INDIANA SPECIES OF KOLLA

1. Color brownish gray or blackish.....*hartii.*
1′. Color greenish with conspicuous bands across the vertex and pronotum .....2.
2 (1′). Fore-wings with conspicuous black lines along the veins ..... *bifida.*
2 (1′). Fore-wings deep uniform green.....*geometrica.*

Kolla bifida (Say). (Fig. 5)

Say, Thomas. *Jour. Acad. Nat. Sci. Phila.* 6: p. 313, 1831. *Tettigonia.*

Moderately robust, blunt headed greenish insects, with white transverse bands on head and pronotum and veins of fore-wings black. Length to tip of fore-wings, 5.5-6 mm.

Fig. 5. *Kolla bifida* (Say), X 6½.

General color green and black. Vertex black with two white spots at apex and a yellowish or white median and basal band. Pronotum greenish, anterior margin black followed by a white band, posterior margin white preceded by a black band. Fore-wings with veins broadly black.

Last ventral segment of female with the posterior margin roundingly produced. Male plates short, less than half the length of the long narrow pygofers.

This species was described from Indiana.

Collection data:

Decatur Co., Oct. 15 (H. O. D.); Harrison Co., Aug. 30 (J. J. D.); Kosciusko Co., July 15 (G. E. G.); Tippecanoe Co., July 20 (G. E. G), Oct. 8 (H. O. D.). All specimens swept from grass and weeds in low places.

Kolla hartii (Ball)

Ball, E. D. Pro. Ia. Acad. Sci. 8: p. 61, 1901, *Tettigonia.*

Rather uniformly brownish gray or blackish insects, smaller than *bifida.* Length to the tip of fore-wings, 3.75-5 mm.

The female is brownish gray. Ocelli and a pair of spots on posterior margin of vertex black. Pronotum with irregular black spots near anterior margin. Scutellum with dark triangular spots in basal angles. Veins of fore-wings pale, claval margins often lined with light blue. The male is shining black, circles around ocelli and apex of scutellum pale. Spot on apex of scutellum white.

Last ventral segment of female truncate, slightly excavated either side of a small median tooth. Male plates wide at base but taper to acute points; very short, less than half the length of pygofers.

Collection data:

Harrison Co., Aug. 30 sweeping grass (J. J. D.).

Genus *Helochara* Fitch

In this genus the head is wider than the pronotum, much broader than long; apex conical, obtusely angled, the reflexed portion of front is elevated and prominent. Pronotum is very long, six-angled. Scutellum small, less than half as long as pronotum. Veins of fore-wings distinct; venation simple, three anteapical and five apical cells present.

Only one species of this genus is known to occur in the United States.

Helochara communis Fitch

Fitch, A. *Homop. N. Y. State Cab.* p. 56. 1851.

A rather small, but robust, green species. Length to tip of fore-wings, male 4-5.5 mm.; female 6-7 mm.

General color green, often fading to pale yellowish, but stripes along claval suture always dark. The whole dorsal surface is distinctly punctate.

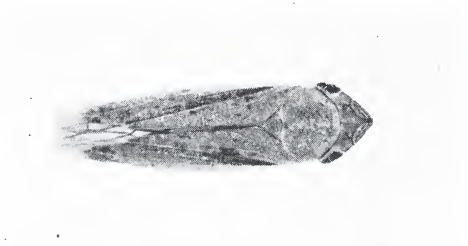


Fig. 6. *Helochara communis* Fitch., X 6½.

Last ventral segment of the female is but little longer than the preceding, the posterior margin slightly produced in the middle. Male plates broadly triangular, slightly longer than the pygofers.

Collection data:

Tippecanoe Co., July 20 (G. E. G.); Oct. 16 on sedge along edge of pond (H. O. D.).

Genus *Graphocephala* Van Duzee

Leafhoppers with the head narrower than the pronotum; vertex flat, apex obtusely rounded, margin distinct and acutely angled with the front; the front not inflated. The pronotum is narrowed anteriorly, not over twice the length of the scutellum. The fore-wings are long and opaque, the veins indistinct but simple.

Two of the three species known to occur in the United States have been taken in Indiana.

KEY TO THE INDIANA SPECIES OF GRAPHOCEPHALA

1. Vertex marked with black lines; not over 6 mm. long.....*versuta.*
1'. Vertex unmarked except for the black border; over 8 mm. long .....*coccinea.*

Graphocephala coccinea (Forst.) (Fig. 7)

Forster, J. R. Novae Species Insectorum; Centuria I. 1771, *Cicada.*

The members of this species are rather large, cylindrical, elongated red and blue striped insects. Length to tip of fore-wings, 8-9 mm.

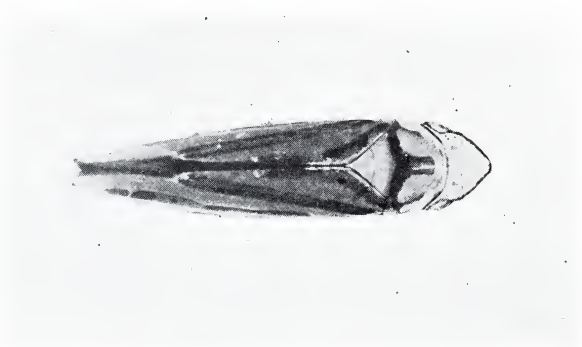


Fig. 7. *Graphocephala coccinea* (Forst.), X 6½.

The head is bright yellow or orange with anterior margin of vertex black. The pronotum is reddish with anterior and posterior and a broad median stripe deep green or blackish. The forewings with brilliant red and green stripes.

Coccinea is one of our most beautiful and easily recognized leafhoppers.

Collection data:

Bartholomew Co., Oct. 15 (H. O. D.); Clark Co., July 4 (P. S. C.), 15 (B. E. M.); Lawrence Co., June 27 (L. F. S.), Aug. 21 on mulberry (L. I. M.); Morgan Co., June 28, Aug. 7 (L. I. M.), July 13 (R. R. H.); Parke Co., June 25 on *Impatiens pallida* (F. H. T.); Porter Co., Aug. 11 (J. J. D.), Sept. 1, 2, 4 (B. E. M.); Rush Co., June 26, 30 on swamp grass, Sept. 1 on shrubs (R. R. H.); St. Joseph Co., Aug. 22 on wild grape and honey locust (A. W. T.); Tippecanoe Co., May 7 (P. S. C.),

June 26 (G. E. G.), July 7-20 (J. J. D.), 19 on swamp weeds, 20 on willow (A. W. T.), Aug. 21 (G. E. G.), Sept. 25 on honey locust (A. W. T., B. E. M.), Oct. 1 on willow (A. W. T.), 8 on maple (A. W. T., W. D. M.).

Graphocephala versuta (Say). (Fig. 8)

Say, Thomas. *Jour. Acad. Nat. Sci. Phila.* 6: p. 311. 1831, *Tettigonia.*

This species has much the same form as *coccinea* but is smaller. Length to tip of fore-wings, 5-6 mm.

The vertex is pale yellow with a black stripe bordering on its margin and a pair of black median parallel lines which connect in front to a pair of interrupted lines which parallel the margins of vertex and

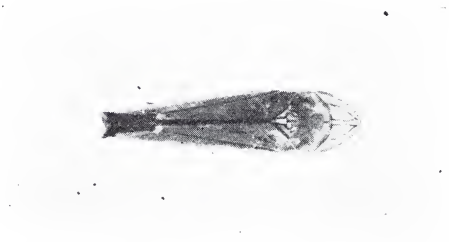


Fig. 8. *Graphocephala versuta* (Say), X 6½.

extend to the posterior margin of the vertex; the space between the parallel lines whitish. The pronotum is yellowish anteriorly, greenish posteriorly, often with red stripes. Scutellum yellowish or red, with black markings. Fore-wings greenish blue, claval suture blue either side of which is a broad red or yellowish stripe which often extend over the pronotum and meet on the vertex.

Collection data:

Bartholomew Co., Oct. 15 on alfalfa (H. O. D.); Clark Co., July 15 (B. E. M.); Decatur Co., Oct. 15 (H. O. D.); Dubois Co., Sept. 11 (G. E. G.); Lawrence Co., July 1, Aug. 21 on mulberry (L. I. M.); Marion Co., Oct. 15 (G. E. G., H. O. D.); Ripley Co., Oct. 15 (H. O. D.); Tippecanoe Co., July 20 (J. J. D.), Oct. 8 (H. O. D.).

Genus *Draeculacephala* Ball

In this genus the vertex is long and acutely angled. The pronotum with lateral margins parallel, either narrower than or equal in width to the eyes. The fore-wings are long, narrowing apically, green, and with apical and anteapical cells irregularly reticulately veined.

Five species of this genus *angulifera* (Walker), *mollipes* (Say), *minor* (Walker), *novaeboracensis* (Fitch), and *inscripta* (Van Duzee) should occur in Indiana as they have been found in the adjoining states. However, the writer at the present time has specimens of only one species, *mollipes,* that have been taken here.

Draeculacephala mollipes (Say). (Fig. 9)

Say, Thomas. *Jour. Acad. Nat. Sci. Phila.* 6: p. 312. 1831, *Tettigonia.*

Bright green insects with vertex long and acutely angled. Length to tip of fore-wings, 6-9 mm.

Vertex, anterior part of pronotum and scutellum yellow. Vertex with two small apical dots, lines on reflexed portion of front, a median and pair of lateral lines brown. Face yellow to fuscous. Disc of pronotum and fore-wings bright green, the veins and margins light.

Fig. 9. *Draeculacephala mollipes* (Say), X 6½.

The vertex very long in female, distinctly longer than broad. The last ventral segment of the female with posterior margin sinuate on either side of angularly produced median lobe. Male valve short and broad, angularly produced.

This is a very common species on many of the grasses and occurs throughout the state.

Collection data:

Bartholomew Co., Oct. 15 (H. O. D., G. E. G.), Decatur Co., Oct. 15 (H. O. D.); Johnson Co., Oct. 15 (H. O. D.); Jennings Co., Oct. 15 (H. O. D.); Kosciusko Co., Aug. 8 (G. E. G.); Lawrence Co., July 20, (H. O. D.); Morgan Co., July 13 (R. R. H.), Oct. 10, 21 on clover, Nov. 7 (L. I. M.); Parke Co., July 25 (F. H. T.); Porter Co., Aug. 6-10 (J. J. D.); Ripley Co., Oct. 15 (H. O. D.); Rush Co., June 18, 30 (R. R. H.); St. Joseph Co., June 16, Aug. 21 (A. W. T.); Tippecanoe Co., May 9, June 21 (H. O. D.), July 23 (G. E. G.); Aug. 5 at light (J. J. D.), Sept. 26 (R. R. H.); Oct. 6 (R. R. H.), 8 (H. O. D.).

Genus *Pagaronia* Ball

In this genus the head is conical; the vertex as long as pronotum and nearly as long as wide, with the lateral margins in a continuous line with the curve of the compound eyes. The pronotum is less than twice the length of the scutellum. Venation of fore-wings is simple.

One species of this genus occurs in Indiana.

Pagaronia tripunctata (Fitch). (Fig. 10)

Fitch, A. *Homop. N. Y. St. Cab.* p. 55. 1851, *Tettigonia.*

A whitish species with veins of fore-wings black. Length to tip of fore-wings, 5 mm.

This species resembles the members of the genus *Kolla* very much. The general color is light yellowish white with the veins of the fore-wings and three distinct spots on the vertex black.

Fig. 10. *Pagaronia tripunctata* (Fitch.), X 6½.

The last ventral segment of the female is nearly twice as long as the preceding, the posterior margin slightly rounded. The male plates broad at base, narrowed posteriorly, almost as long as pygofers.

Collection data:

Decatur Co., Oct. 15, sweeping brush along creek (H. O. D.).

Genus *Evacanthus* Le Peletier and Serville

In this genus the head is broad and short, the vertex is wider than long; the ocelli are located close to the margin of vertex. The pronotum is short and the fore-wings are without anteapical cells.

One species of this genus has been taken in the state.

Evacanthus acuminatus (Fabr.) (Fig. 11)

Fabricius, J. C. Entomologia Systematics 4: p. 36. 1794, *Cicada.*

Broad, plumb leafhoppers. Length to tip of fore-wings, 5-6 mm.

The face and body are black beneath. Male is black above, with spots on vertex and veins and a stigmal spot on fore-wings whitish. Female is testaceous above with spots on vertex, anterior border of pronotum, and disc of scutellum black.

There is a median keel on vertex and a less elevated one crossing it near the apex. The fore-wings are comparatively short, reaching the apex of abdomen. The last ventral segment of the female is long, with posterior margin truncate and slightly sinuate at center. Male valve short, and broad.

This species is northern in distribution.

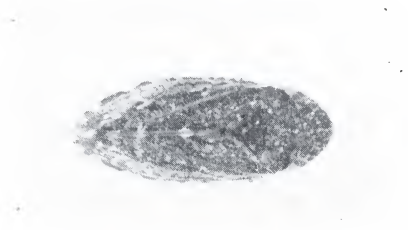


Fig. 11. *Evacanthus acuminatus* (Fabr.), X 6½.

Collection data:

St. Joseph Co., Aug. 12 on blue grass (A. W. T.).

LIST OF REFERENCES CITED

1. Ball, E. D. The Genus Draeculacephala and its Allies in North America (Rhynchota, Homoptera). *Florida Entomologist* 11: p. 33-40, 1927.

2. Ball, E. D. The Food Plants of the Leafhoppers. *Annals Entomological Society of America* 25: pp. 497-501, 1932.

3. Lawson, P. B. Concerning *Cicadella hieroglyphica* var. *dolobrata* Ball (Homoptera, Cicadellidae). *Canadian Entomologist* 61: pp. 69-70, 1929.

4. Say, Thomas. Descriptions of new North American Hemipterous Insects, belonging to the first family of the section Homoptera of Latrielle. *Jour. Acad. Nat. Sci. Phila.* 6: pp. 299-314, 1831.

5. Van Duzee, E. P. Catalogue of the Hemiptera of America North of Mexico, excepting the Aphididae, Coccidae and Aleyrodidae. *Univ. Calif. Pub. Tech. Bull.* (Ent.) 2, 1917.

16—48585

SOME ANATOMICAL FEATURES OF THE TIGER SNAIL, *ANGUISPIRA ALTERNATA* (SAY)

David T. Jones, Indiana University

The present study is an attempt to understand the organization of the viscera of the very common Indiana land snail, *Anguispira alternata*, a widespread complex, which up to this time has been generally left in one species. The study has been made at Indiana University, Zoology Department, in connection with a study on secretion of shell, particularly of this same snail. All specimens were collected at Bloomington, Indiana.

The anatomical drawings have been taken from several dissections, perhaps twenty or twenty-five in number. After killing the snail, the soft parts were extracted from the shell by immersing shell and snail in nearly boiling water for from fifty to sixty seconds. Some of the dissections were made from fresh material, other from material hardened several days in 70% and later 50% alcohol. The histological sections were made from four animals. Fixation was in Carnoy-Le Brun fluid or in a special fixative of equal parts of 1% chromic acid, 3% potassium dichromate, saturated solution of corrosive sublimate, 95% alcohol, and 10% formalin which I was trying experimentally. Tissues were fixed from one to three minutes. After passing through the usual gradation of alcohols, xylol, xylol-paraffin, and embedding, the paraffin sections were cut at either five or ten micra. Ehrlich's acid haematoxylin and eosin, or Heidenhain's iron haematoxylin were the two staining methods used.

The pioneer work on anatomy of land snails in this country was done by Dr. Joseph Leidy for Dr. Amos Binney from 1844-1851, and was published in the first volue of Amos Binney's "Terrestrial mollusks and shells of the United States" in 1851. Three figures were given on the anatomy of *Anguispira* (then *Helix*) *alternata*, which though accurate from the standpoint of representing the structures, were inaccurately labelled. Pilsbry in his "Guide to the study of Helices" (Vol. IX, Series II, Tryon's Manual of Conchology 1894) gives a figure of the genitalia of *Anguispira* (then *Pyramidula*) *alternata*. I have not had access to this article, but I have had copies of the figures during the present study. Valuable comparative material on other species is given in Simpson's "Anatomy and physiology of *Polygyra albolabris* and *Limax maximus* and embryology of *Limax maximus*" (Bull. N. Y. State Mus. No. 40, Vol. 8, Oct. 1901) and in Simroth's and Hoffmann's work in Bronn's "Klassen und Ordnungen des Tier-Reichs" (Bd. 3, Abt. 2, 1908-1928).

While lack of space makes it imperative that the figures tell their own story, the following observations are given as supplementary:

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

The digestive system (Fig. 3) is remarkably adapted to the extension of the animal. The buccal mass, containing the jaw and radula (not shown) are pulled well down into the body when the snail emerges from its shell. How much of the oesophagus is involved in this stretching is problematic, though its slender size seems to allow it to extend into the expanded body. Kinked salivary ducts perhaps allow for movement of the head region in crawling, feeling, and feeding. The apical (right) lobe of the liver and lower (left) lobe open by wide hepatic ducts near the origin of the intestine as shown in figures 3 and 7. Simpson explains that the liver of snails is more like a pancreas in function since bilary liquids are absent. He suggests the name "digestive gland" rather than "liver." Other authors however state that the hepatic cells store digested nutritive material absorbed from the intestine, which is a function of the liver. Golden secretion granules (Fig. 9) are very apparent in the cells of the lobules. Of 105 snails "pulled" on April 20, 1932, 5 had black livers, though all had been collected on the same stone wall on I. U. campus. The ordinary color of the liver is a rich brown, almost tan. The stomach shows no differentiation of a crop. If that organ be present, it is probably represented by a slight swelling of the oesophagus shown by some specimens. The path of food and of wastes is as follows: mouth, buccal cavity (with calcareous jaw and radular ribbon), oesophagus, stomach, intestine, rectum, and anus. The sigmoid loops of the intestine, where most of the absorption takes place, are pressed into the liver. Microscopic examination of the oesophagus and stomach of *Angulispira alternata* shows that the food of the specimens examined consists mostly of bits of superficial angiosperm tissue, as disclosed by the radular filings of cutin, epidermal cells, occasionally epidermal cells with palisade layer, tracheae, and plant hairs. There are also many spores and filaments of fungi, possibly Phycomycetes or Ascomycetes, and occasionally bacteria and diatoms. Food particles, except for insoluble material, are rarely identifiable beyond the stomach.

The circulatory system (Figs. 2 and 6) has been worked out only in its grosser aspects. The course of the blood is said to be: auricle, ventricle, aorta, arteries, sinuses where blood bathes the organs, pulmonary sinus, network of veins on roof of pulmonary cavity where blood is aerated, pulmonary vein, auricle. Some authors report in certain parts of the body that arteries lead to capillaries, from which veins lead to pulmonary sinus, then through fine veins of the renal organ or of the pulmonary roof to the pulmonary vein. The circulatory system is said to play an important part in emergence from the shell. "The snail emerges from its shell by forcing the blood into great spaces in its foot and front region, but withdraws by muscular action." (Ellis, British Snails, p. 19.) The anterior part of the body when retracted is turned outside in. Likewise the tentacles are pulled in by retractor muscles "like turning the fingerstall of a glove outside in," but are forced out by blood turgor. Ellis states that when blood pressure of the snail is used during copulation for penial erection, the tentacles droop due to withdrawal of blood from the tentacles. Thus snail emergent and retractile movement is largely accomplished by blood turgor working against retractor muscles, instead of extensor muscles vs. retractor

muscles. The blood is practically clear or faintly bluish in those snails having the copper compound, haemocyanin. The Planorbidae have red blood, which Fulton says is due to haemoglobin (Quart. Jour. Mic. Sci. N. S., Vol. 66, p. 364, 1922). The number of heart beats varies greatly in *Anguispira alternata* due to activity, temperature, and possibly other factors. In retracted tiger snails of various ages at room temperature, the heart beat varied from 37 upward beyond 60. During activity the larger number increased, the highest count being 92 beats per minute. In spite of the variation, the pulsation is very regular in this species, in marked contrast to the irregular flare-up in rhythm observed in *Polygyra tridentata* (Say).

Anguispira alternata shows no muscular waves on the sole of the foot in locomotion. In *Polygyra clevata* (Say) 52 pedal waves per minute are to be observed confined to a broad median part of the sole when the animal is progressing. *In Anguispira alternata* longitudinal wrinkles appear in the sole during locomotion, and under the binocular ciliary action is evident on the sides of the foot between the sole and lateral groove of the foot.

The nervous system consists chiefly of a supraoesophageal ganglionic mass and an infraoesophageal ganglionic mass, connected to the former by two connectives on either side. These have divisions as shown (Fig. 5).

In connection with the reproductive system, I have the following notes. *Anguispira alternata* is hermaphroditic but not viviparous. I have no data as to when copulation occurs. The ovotestis of a specimen taken on April 16, 1932, shows in section (Fig. 8) large almost mature eggs and immature male germ cells, the latter being separated from the former in the organ. Mature male germ cells are present in this same section in the spermatheca, the duct of the same, and in the seminal groove (Fig. 7). Egg laying in 1932 started about June 1st and continued well through June in specimens kept in containers. All eggs laid in these containers (8 in all) were solitary. F. C. Baker (Mollusca of Chicago Area, Part 2, p. 208, 1902) found eggs of *alternata* in agglutinated clusters of from 20 to 80 eggs, and placed the hatching time at 30 days. In my containers 2 eggs laid around June 1st, hatched in about two weeks. The young snails had whorls of 1¼ and 1½ whorls respectively when first found. The eggs are ovoid, with a very elastic shell which is frosty white. This shell is enclosed with an almost-liquid gelatinous layer. Inside the shell is a great amount of semi-fluid material in which the embryo is suspended as a mere speck. The diameter of the eggs vary. One measured 3 x 2½ x 2½ mm., though the diameter may be as low as 1.7 mm.

The eggs and sperm are each formed in different parts of the ovotestis and mature at different times. Each descend through the hermaphroditic duct at different seasons. Shortly after its convoluted portion this duct separates into a seminal grove and an oviduct. Near the junction of the hermaphroditic duct with these partially separated tubes is a small pocket, by some conceived to be a seminal vesicle, by others, an accessory gland of the duct called a talon (ac. g. of Fig. 4).

In the same region a large banana-shaped albumen gland opens into the reproductive tract. It is suposed to supply the albuminous coats for the eggs. In the region of the partially separated tubes, the sperm duct or seminal groove is surrounded by glands, while the oviduct wall is much folded to form uterine lobes, which are so extensive that they form uterine pouches opening into the oviduct (ut. of Figs. 4 and 7). Peculiar cells (x. of Fig. 10) are perched on or are lodged quite regularly between the wall cells of these uterine lobes. They were found in snails killed on April 16 and May 2, 1932. As quite mature live germ cells were found in the ovotestis of several individuals examined on June 28, 1932, I can not conceive of these as being a stage of the developing sperm. They may be developing egg cells though if such be the case, they are much smaller than the eggs in the ovotestis, which might be interpreted that they are eggs which have undergone a pycnotic change. Another likely explanation is that they are parasites, as Leidy's spermathecal parasites figured by Simpson (reference as above, p. 261, Pl. 13, Fig. 6). The naming of uterine lobes and adjacent structures is yet in confusion. Robson (Quart. Jour. Mic. Sci., N. S., Vol. 66, Fig. 9, p. 176) shows evidently the same organ in a water snail under the name of "oviducal gland." The cells of the wall are the same but no cells corresponding to these (x) cells are present.

Nearer the front of the animal the oviduct and sperm duct separate, the one going into the vestibule, the other as the vas deferens entering the base of the penis sac, within which it terminates in the penis. The duct of the spermatheca, which is especially long in this species, also opens into the vestibule (or vagina). It is independent of the other organs throughout its course. Though data on copulation are lacking, it is supposed that cross-fertilization occurs (parthenogenesis and occasional self-fertilization, however, are known in some aquatic snails). In the tiger snail, it is probable that the ripe sperm cells are mutually transferred from the reproductive system of one snail to that of another snail before the eggs mature. The sperms are stored in the spermatheca until the eggs mature. *Anguispira alternata* has no dart, dart sac, large accessory glands, or flagellum as does the European *Helix pomatia*.

This article is written not only with the research aim in view, but also to point out the chief anatomical features of this snail so that high school and college biology teachers may use the material here given, along with that on *Helix pomatia* in Hegner's textbook, to compile their own laboratory sheets. *Anguispira alternata* is usually abundant near old stone walls, limestone outcroppings, or under logs in moist places, anywhere in the northern states from Iowa to the Atlantic seaboard. It is often as plentiful in town as in the woods. Its flame-red markings sometimes separated into red spots, or at other times jaggedly united show very conspicuously on its yellowish brown groundwork (Fig. 11). Its gregarious habits are also favorable for collecting. Tiger snails come out of their hiding places in great numbers before or after a thunderstorm, when they can be gathered literally by the hundreds.

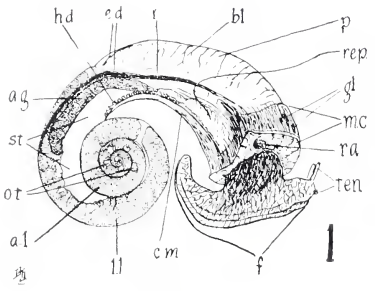
Figure Titles and Explanation. *Anguispira alternata* (Say).

1. Apical view of animal, X 4, as it was pulled from shell after immersing in warm water to loosen the hold of the columellar muscle.
2. Basal view of animal, X 4.
3. Digestive system, apical view.
4. Reproductive system, circumferential view.
5. Nervous system, dorsal view.
6. Heart, renal organ, and adjacent structures, viewed basally.
7. Vertical section, near midline, through whorls of spire and upper part of body whorl. Drawn to scale. Special fixative (see text). Stain-Iron hematoxylin.
8. A small lobule of the ovotestis in section. Special fixative. Outline by camera lucida. Iron hematoxylin.

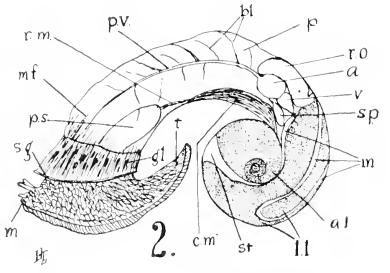
9A. Section through a lobule of the liver. Special fixative. Outline by camera lucida. Ehrlich's acid hematoxylin and eosin.

9B. Enlargement of region between a and b of Fig. 9A. Outline by camera lucida.

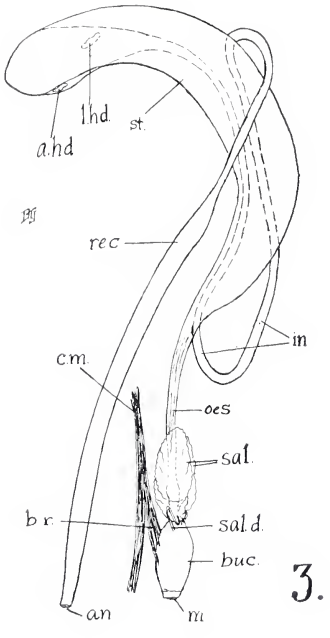
10. Section of wall of uterine lobe. Special fixative. Outline by camera lucida. Iron hematoxylin.
11. Side view and basal view of shell of *Anguispira alternata*.


hd
ed
bl
p
rep
ag
gl
mc
st
ra
ten
ot
al
cm
f
ll

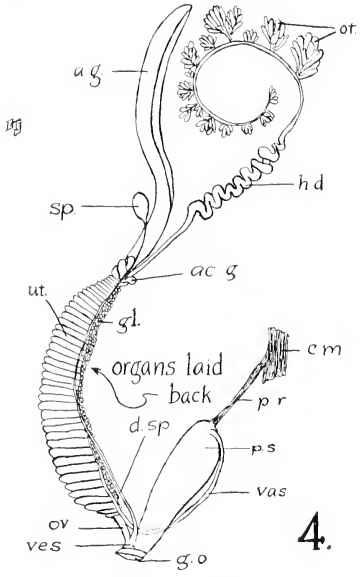
1


pv
bl
p
r.m.
r.o
a
mf
v
sp
ps
sg
gl
m
al
cm
st
ll

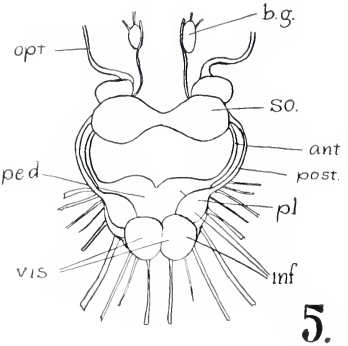
2.


lhd
a.hd
st
rec
in
cm
oes
sal
sal.d
b.r
buc
an
m

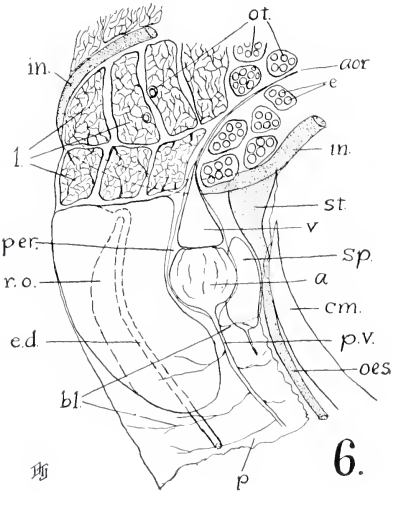
3.


ot
ag
hd
sp
ac.g
ut
gl
cm
organs laid back
p.r
d.sp
ps
vas
ov
ves
g.o

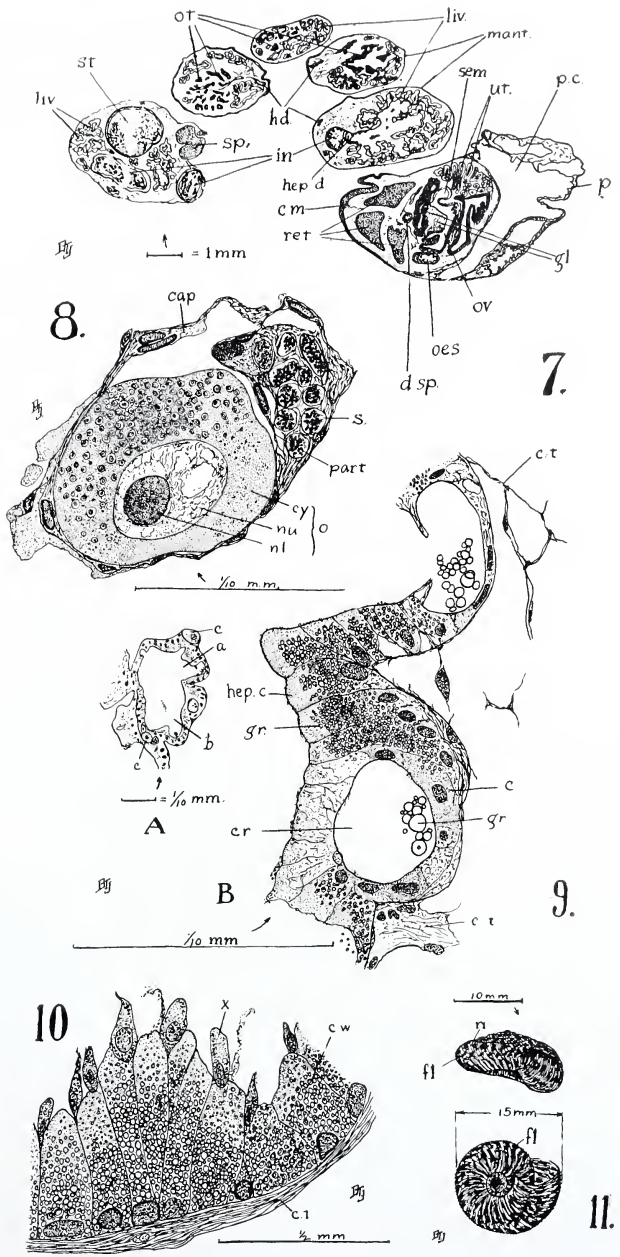
4.


b.g.
opt
so.
ant
post.
ped
pl
vis
inf

5.


ot
in
aor
e
l
in
st
v
per
sp
r.o.
a
cm
e.d
p.v
oes
bl
p

6.


ot
liv.
mant.
st
liv
sem
ut.
p.c.
hd.
sp.
in
hep.d
p
cm
ret
gl
= 1mm
ov
oes
d.sp.
7.
8.
cap
s.
part
cy
nu
nl
o
1/10 mm.
c.t
c
a
b
hep.c
gr.
= 1/10 mm.
A
cr
B
9.
1/10 mm
10
x
cw
c.l
1/2 mm
10 m.m.
n
fl
15mm
11.

KEY LETTERS FOR ALL FIGURES

a auricle
a-b lines between which enlargement represented in Fig. 9 was made
ac.g accessory gland or talon
a.g. albumen gland
a.h.d. apical hepatic duct
a.l. apical lobe of liver
an. anus
ant. anterior connective
aor. aorta
b. see a-b, above
b.g. buccal ganglion
bl. blood vessel
b.r. buccal retractors
buc. buccal mass
c. non-granular cell
cap. capsule
c.m. columellar muscle
cr. crypt
c.t. connective tissue
c.w. cells of wall of uterine lobe
cy. cytoplasm
d.sp. duct of spermatheca
e. eggs
e.d. excretory duct
f. foot
fl. flame bands of color
gl. glands
g.o. genital opening
gr. granules
h.d. hermaphroditic duct
hep.c. hepatic cell
hep.d. hepatic duct
in. intestine
inf. infraoesophageal ganglionic mass
l. lobules of lower lobe of liver
l.h.d. lower hepatic duct
liv. liver
l.l. lower lobe of liver
m. mouth
mant. mantle of the spire
m.c. mantle collar
m.f. muscle fibers
nl. nucleolus
nu. nucleus
o. ovum or egg
oes. oesophagus
opt. optic nerve
ot. ovotestis or hermaphroditic gland
ov. oviduct
p. pulmonary cavity, roof of
part. partition
p.c. pulmonary cavity
ped. pedal portion of ganglionic mass
per. pericardial cavity
pl. possibly the pleural portion of ganglionic mass
post. posterior connective
p.r. penis retractor
p.s. penis sac or verge sac
p.v. pulmonary vein
r. rectum
r.a. respiratory aperture
rec. rectum
rep. reproductive organs (accessory)
ret. retractor muscles
ri. rib on shell
r.m. retractor muscle of penis
r.o. renal organ
s. immature male germ cells
sal. salivary glands
sal.d. salivary ducts
sem. seminal groove
s.g. supramarginal groove of mantle collar
s.o. supraoesophageal ganglia
sp. spermatheca
st. stomach
t. tail
ten. tentacles
ut. uterine lobes
v. ventricle
vas. vas deferens
ves. vestibule
vis. visceral portion
x. problematic cell in uterine lobe.

SOME OBSERVATIONS ON THE REPRODUCTIVE CYCLE OF THE INFUSORIAN, ICHTHYOPHTHIRIUS MULTIFILIIS

Nathan E. Pearson, *Butler University*

A year ago the writer[1] described an epidemic of ichthyophthiriasis which had appeared among the fishes in an Indianapolis pond. The disease was attributed to the holotrichous infusorian, *Ichthyophthirius multifiliis* Fouquet. This fish parasite is common in Europe where it frequently causes serious epidemics among freshwater fishes in aquaria and hatchery ponds. In this country the disease has also appeared from time to time in widespread localities, and the parasite causing it has been identified as the same species as the one producing the disease in Europe. It may have been introduced with some of the imported fishes. The European carp is a possible source.

There are a number of papers in various European publications which relate to the disease; a few are concerned with the nuclear changes during the reproductive cycle. I have found no record of a study of these changes in American material. The purpose of this paper is to record the results of observations that were made on the life history of material that was collected during the above mentioned epidemic, and to call attention to the interesting life cycle of this parasitic infusorian. The work is incomplete in respect to details because of the lack of material which can be collected successfully only when the disease appears in epidemic form. The work of Buschkiel[2] contains the most satisfactory account of the reproductive cycle. This study shows some differences in the nuclear cycle from that reported by Buschkiel.

The typical infusorian carries on the reproductive process by binary fission which is interrupted from time to time by a sexual process. *I. multifiliis* may divide by binary fission; this is followed by sporulation, a process of multiple division, during which autogamy occurs. Sporulation ends in the production of the reinfecting spores.

The Adults. In epidemic form the adults are found in abundance in the gills and skin of many fishes. They have a characteristically large macronucleus and a micronucleus which was found to migrate into the macronucleus during the earlier parasitic stages. A short time after this migration the micronucleus was seen with difficulty and later not at all. For a microscopical study of these nuclei pieces of gill tissue containing an abundance of parasites were fixed with saturated

[1] Pearson, N. E. Ichthyophthiriasis among the fishes of a pond in Indianapolis. Proc. Ind. Acad. Sci. **41**:455-463. 1931 (1932).

[2] Buschkiel, A. L. Beiträge zur Kenntnis des Ichthyophthirius multifiliis Fouquet. Arch. f. Protistenk. **21**:61-102, 1910.

mercuric chloride without acetic, Zenker's, Flemming's strong solution, or Kleinenberg's picro-sulphuric. Sections were stained with Delafield's hematoxylin or Heidenhain's iron-hematoxylin, and counter-stained with eosin or acid fuchsin. By none of these methods could the micronucleus be located in the later adult stages. A characteristically small spindle shaped body which took the counter-stains was present, but a study of later stages showed this to be a different structure.

A few observers have reported that the adults may undergo binary fission in the tissues of the host. Although a few hundred specimens of variable sizes were studied in the gills, none were found dividing. If division occurs in the tissues of the host it probably occurs only in mature adults which for some reason fail to free themselves at the time they would normally begin the sporulation process.

The mature adults migrate from the tissues of the host and may settle down directly and begin the process of sporulation, or they may swim actively for a time, divide by transverse fission and then settle down. A temporary gelatinous cyst is secreted outside of the cilia. Within the cyst multiple division occurs during which all cells are kept in constant rotation by actively moving cilia.

Sporulation. The adults may attain a length of 0.8 mm., but many smaller ones escape and undergo sporulation. The smallest one observed in this laboratory was 0.14 mm. The smaller individuals produce fewer reinfecting spores than the larger ones, but the nuclear changes are the same in both. The divisions within the cyst are regular, all of the daughter cells being found in the same stage of development. Sporulation was usually completed within 22 to 30 hours in the larger adults whereas the smaller ones usually completed the process in less time. The nuclear changes in the reproductive cycle occur in the cells which follow the second from the last division; consequently, the material for the study of the nuclear changes should be taken toward the close of the sporulation process.

Micronuclear Cycle. The material that was used for this study was fixed in Zenker's and stained with Delafield's hematoxylin or Heidenhain's iron-hematoxylin, and counter-stained with eosin or acid fuchsin. Iron-hematoxylin was not satisfactory inasmuch as it had a tendency to stain cytoplasmic structures in the same manner it did the micronuclei.

During the process of multiple division each cell was found to divide by ordinary fission, until each attained a diameter which averaged 0.035 mm. During these cleavages the macronucleus was constricted in two equal parts, but no micronucleus could be discovered. As yet no worker has been able to locate a micronucleus during these divisions. When the above mentioned cell size was reached the sexual cycle was initiated by the migration of a micronuclear body from the macronucleus. This first detached micronuclear body was first observed just at it began to migrate from the macronucleus. At that time it stained slightly deeper than the macronucleus, its outlines were only fairly sharp, and the chromomeres making up the structure appeared the same as those of the macronucleus. It measured 0.00348 mm. in

diameter. As the body migrated from the macronucleus a trail of chromatin followed it. During the migration the body enlarged, at the same time gradually lost its staining capacity, became ellipsoid and formed into a spindle on which there were many thick thread-like chromosomes. Then followed a division of the spindle into two parts; the daughter nuclei moved to opposite ends of the cell, at the same time contracting and consequently taking more stain. During this contraction the division of the cell took place so that each daughter cell received one of the micronuclear bodies. After the division of the cell the micronuclear body continued to contract until it became an intensely staining nucleus.

Whether the division of this micronuclear body represented a reductional division could not be determined from a study of the chromosomes; but the chromosomal condition was suggestive of the so considered reductional division in Paramoecium.

A second micronuclear body then became detached from the macronucleus in the same manner that the first body became detached. It was slightly smaller than the first measuring approximately 0.003 mm. in diameter. As it migrated from the macronucleus with a trail of chromatin following, it became ellipsoid and formed into a spindle. While this change was progressing the first detached body likewise formed a spindle.

The structure of the chromatin on these spindles and the nature of the division that followed could not be determined, because Zenker's reagent was not an ideal fixative for the spindles and the material for the study of this particular stage was not abundant. However four nuclei, all of the same size, resulted from the change. Two of these nuclei fused while still ellipsoid. The fusion nucleus which resulted contracted, exhibited a deeply staining chromatin network during the early stages, and later became an intensely staining nucleus measuring approximately 0.0025 mm. in diameter. The remaining two nuclei became greatly enlarged and gradually lost their staining capacity during the contraction of the fusion nucleus. The two structures then fused into a single spherical body that filled the central half of the cell. The material in this body fixed and stained very poorly thereby indicating disintegrative changes. This material finally intermingled with the cytoplasm of the cell.

The final division in the process of sporulation followed. In this division the micronucleus became spindle shaped and took up a position at the side of the cell between the macronucleus and the cell wall. Its division just preceded the cytoplasmic cleavage. The macronucleus divided amitotically as in earlier divisions. The resultant daughter cells then became the reinfecting spores by slight cytoplasmic changes.

From the above described changes it is seen that the spores which initiate a new cycle in the life history contain a macronucleus and a single micronucleus; the former derived from the original micronucleus out of which micronuclear material had migrated, the latter from the fusion of two micronuclei which, it is reasonable to conclude from the degenerating nuclei, had undergone divisions in which the chromosomal number had been reduced.

A third body about one-fourth to one-third the size of the other detached bodies was observed to separate from the macronucleus in some of the cells following the migration of the second detached micronuclear body. It became spindle shaped as the preceding two; but its changes could not be followed. Whether this third detachment was present in all cells could not be determined; however, a small micronuclear body was observed in a few cells that contained the fusion nucleus, and a few of the mature reinfecting spores were observed to contain a small micronuclear body in addition to the micronucleus. The function of this detached body is not understood unless it represents micronuclear material that failed to migrate from the macronucleus during the earlier migrations.

The small, usually spindle shaped structures that were referred to in connection with the macronucleus of the adults were also present in the cells resulting from multiple division. Some of the macronuclei contained several, others a single one. They were observed to increase in size and to be cast out of the macronucleus from time to time. The macronucleus of the cell undergoing the final micronuclear changes contained a single, yet the most characteristic of these bodies. These structures may have something to do with the metabolic activity of the cell.

The new micronucleus was found to migrate into the macronucleus some time after the parasitic spores had entered the tissues of the host. It entered the macronucleus while still a deeply staining body and then enlarged exhibiting a chromatin network apparently continuous with that of the macronucleus. At this time the parasite measured approximately 0.13 by 0.06 mm.

The free swimming adults which measure about 0.14 mm. in diameter undergo the process of sporulation slowly if at all. This seems to indicate that the micronucleus bears a relationship to the macronucleus which is necessary to initiate the process of cell division and this relationship is not reëstablished until some time after the micronucleus has entered the macronucleus.

SUMMARY

Mature adult parasites have a micronucleus that is concealed in the macronucleus during the greater part of the vegetative stage, and also during the greater part of the sporulation process. It migrates from the macronucleus in two separate migrations that take place in the first two of the last three cells of the sporulation process. The first detached body divides and the daughter nuclei are distributed to daughter cells. The daughter nuclei of the first detached body and the second detached body divide forming four nuclei of equal size. Two of these fuse (presumably daughter nuclei of the first and second detached bodies) and the remaining two degenerate. A single cell division follows the formation of the fusion nucleus; thus giving rise to the reinfecting spores which penetrate the tissues of the host and enter into the vegetative state. After a short period of time the micronucleus migrates into the macronucleus.

The fusion of the two nuclei is to be interpreted as the fusion of "gametes"; but what represents the meiotic divisions is problematical. The answer to the question as to whether each of the two detached bodies represent reduced chromatin, or whether the divisions of these bodies represent meiotic divisions must be held in abeyance until a careful examination of the chromosomes can be made. The third detached body further complicates the problem.

A NEW MEDIUM FOR DROSOPHILA CULTURES

S. A. RIFENBURGH, Purdue University

The most commonly used media for Drosophila cultures are banana agar[1], corn meal agar[2] and a few kinds of synthetic media, especially those of Pearl.[3]

Naturally these have their advantages and disadvantages. Banana agar produces large vigorous flies and does not dry out badly, but it is expensive and has a tendency to become contaminated with molds. Corn meal agar, on the other hand, is slightly less expensive but dries out badly and produces smaller, less vigorous flies. The synthetic media are uniformly expensive.

The new medium here described is cheaper than the others, produces flies fully as large and vigorous as any, does not dry out badly and is not unduly susceptible to contamination. If prepared correctly it may be kept for several days without danger of contamination and without requiring the addition of any water.

It is composed of the following materials in the proportion given by weight:

Banana pulp	25%
Water	66%
Corn Meal	4%
"Black Strap" Molasses	3.9% to 4%
Agar	1% to 1.1%
Total	100%

The bananas should be ripe but not rotten. They are to be peeled and pressed through a "potato ricer." Tap water is ordinarily satisfactory; in fact, unless it contains excessive amounts of disinfectants, it is probably better than distilled water because of the minerals present. The corn meal may be either white or yellow: that prepared for use in cooking is good. "Black strap" is a crude New Orleans molasses sold at feed stores. It is probably better than the highly refined product, yet is much cheaper—a gallon costing about fifteen cents. The cheapest grade of agar is perfectly satisfactory but it should be torn apart in order to dissolve easily.

The medium is prepared as follows. The water, corn meal, molasses and agar are stirred up together and autoclaved at 15 lbs. pressure for

[1] Sturtevant, A. H. The North American Species of Drosophila. Carnegie Inst. Wash., publ. 301:16-17. 1921.

[2] Turtox Service Leaflet No. 15. The Culture of Drosophila . . . General Biological Supply House. Chicago, 1930.

[3] Pearl, R., Allen and Penniman. A New Synthetic Medium . . . Am. Nat., 60:357-366. 1926.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

17—48585

one-half to three-fourths of an hour. Next the banana pulp is added, mixed thoroughly with the other materials by means of an egg beater and immediately poured into the culture bottles. If a large batch is being made it may be necessary to supply a small amount of heat to the mixture while the pouring is being done, but the medium should not be allowed to boil, and the pouring should proceed as rapidly as possible. (Four-ounce wide mouth bottles with about 50 c.c. of medium in the bottom are very good for stock cultures.) After pouring, a piece of paper toweling is added to each bottle which is then plugged with cotton. The bottles are allowed to stand for 12 to 24 hours and then autoclaved at 15 lbs. pressure for ten minutes. As soon as cool, they are ready to use.

It is well to inoculate with yeast the day before the flies are placed in the bottles. This may be done by adding to each bottle by means of a clean medicine dropper, about four drops of a yeast suspension made by stirring one-third of a fresh cake of Fleischmann's yeast in an ounce of clean water. This yeast suspension is brought in contact with the entire surface of the medium by shaking the bottle. On the following day there will be a luxuriant growth of yeast which is very inviting to the flies and which tends to prevent the establishment of molds and bacterial contamination from the feet of the flies.

FRESH-WATER MEDUSAE AT TERRE HAUTE, INDIANA

W. P. Allyn and L. J. Rettger

Several references have been made to the occurrence of fresh-water medusae in Indiana. Payne (1924) reports medusae taken from Boss Lake, near Elkhart, Indiana, in 1918 and studies were made on the subsequent appearances of these forms following that date. In 1926 the same author was able to complete his studies on the life history of the form and suggested the name, *Craspedacusta ryderi*, the sexual

generation of *Microhydra ryderi*. The medusa stage, however, did not differ materially from that described by Garman (1916) except in regard to size. Garner and Markle (1932) also discovered fresh-water medusae near Richmond, Indiana, and suggest the same species as that of Payne.

Fresh-water medusae were found in large numbers in the vicinity of Terre Haute, Indiana, during August, September, and the first part of October (1932) in an old gravel pit some three miles north of the city. This body of water was totally shut off from the Wabash river and received its water by drainage from the adjacent land. It was approximately 100 yards wide and one-fourth mile long. So far as known it

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

has never been stocked with fish but is used to a great extent by water birds during migration.

The first medusae were found August 20th; other forms were collected as late as October 10th. They seemed to be near the surface of the water on afternoons of calm bright days. It was observed that the animals disappeared from sight almost simultaneously with the appearance of wind-blown ripples on the surface of the water.

Several hundred of these medusae were collected and kept alive in aquaria in the laboratory for some three weeks. Eggs were shed profusely in the water but no development occurred. Examination of some fifty animals indicated that they were all females. This is not inconsistent with Payne's (1924) theory that the hydroids are either male- or female-producing. These medusa females probably arose from female-producing hydroids only that perchance made entrance into this body of water.

The medusa form conformed well to those described by Garman (1916) except in regard to size, the former being larger. Without the life history at hand, it is believed that they belong to the species Craspedacusta ryderi, as suggested by Payne (1926).

REFERENCES

Garman, H. 1916. The sudden appearance of great numbers of fresh-water medusae in a Kentucky creek. Science, Vol. **44.**

Garner, M. R. and Markle, M. S. 1932. The occurrence of fresh-water medusae near Richmond, Indiana. Proc. Ind. Acad. Sci., **41**, 431-432.

Payne, F. 1924. A study of the fresh-water medusa Craspedacusta ryderi. Jour. Morph., **38**, 387-430.

Payne, F. 1926. Further studies on the life history of Craspedacusta ryderi, a fresh-water hydromedusan. Biol. Bul., **50**, 433-443.

THE MASKING OF SEPIA BY WHITE, TWO RECESSIVE EYE-COLORS IN DROSOPHILA

FLOYD T. ROMBERGER, JR., Purdue University

During the course of a discussion on the dilution effects produced by various eye-colors upon each other in Drosophila, there arose the question of the color of an individual homozygous for both White and Sepia. At the time, no definite answer could be given; although it was suggested that they would appear most likely as sepia-eyed flies, judging from the fact that homozygous Sepia-Peach individuals were known to approach so nearly the sepia color that it was extremely difficult to separate them into distinct classes.[1] Search in numerous publications failed to yield satisfactory information upon the subject. Consequently, as the best method for determining the solution to the problem, it was decided to produce a strain, homozygous for the characters involved, and then to observe the result of the combination.

A more exhaustive study of the available literature on parallel problems yielded the following data, much of which seemed to indicate that the flies in question would be of the Sepia phenotype: Homozygous Sepia-Scarlet individuals appear indistinguishable from the stock Sepias.[1] Pure Pink-Maroon flies appear maroon-colored.[1] These facts normally would lead one to believe that the dark eye-colors, located on the third chromosome, dominate those lighter ones found in the same group. On the other hand, the knowledge that homozygous White,Pink individuals appear no different from the pure Whites, indicates the possibility that these White,Sepias might have white eyes instead of sepia-colored eyes.[1]

The factor which produces the white eye-color is located on the heterosome or sex-chromosome 1.5 units from the left end, while that which produces the sepia eyes is found on the third chromosome at locus 25.3. Since both of these characters are recessive, they must be present in the homozygous condition before they produce any effect. In the case of the White male, however, only one factor for White needs to be present to produce the character because he possesses only one sex-chromosome instead of two sex-chromosomes, as in the White females.

The first step in this project was the mating of a virgin Sepia to a White male. Figure 1 shows the Punnett square for this cross. In it and the subsequent squares, the following legend was used: Let w represent a gene for White eye-color, with W representing its dominant Wild allelomorph; then s represents a gene for Sepia eye-color with S representing its dominant Wild allelomorph; and Y represents the allosome. In the above cross, all of the offspring (the F_1 generation) were of the Wild or red-eyed type, being found in a ratio of 1 ♂ : 1 ♀.

[1] Bridges, C. B. and T. H. Morgan, '23. The Third-chromosome Group of Mutant Characters in Drosophila. Carnegie Inst. Wash., publ., 327.

The next step was to mate some Wild males from the F_1 generation with their virgin Wild sisters. Figure 2 shows the square depicting the expected results for the F_2 generation. From this it can be seen that the expected ratios are as follows: 3 Wild ♂♂ : 6 Wild ♀♀ : 3 White ♂♂ : 1 Sepia ♂ : 2 Sepia ♀♀ : 1 White,Sepia ♂.

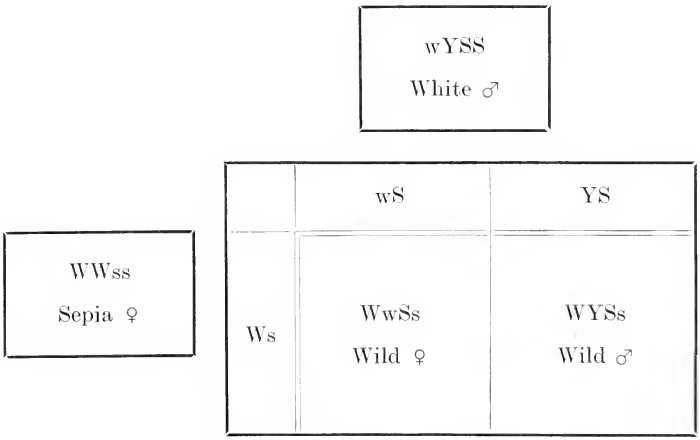


Fig. 1. The production of the F_1 generation by mating a normal White male with a pure Sepia virgin. All of the offspring are of the Wild or red-eyed type.

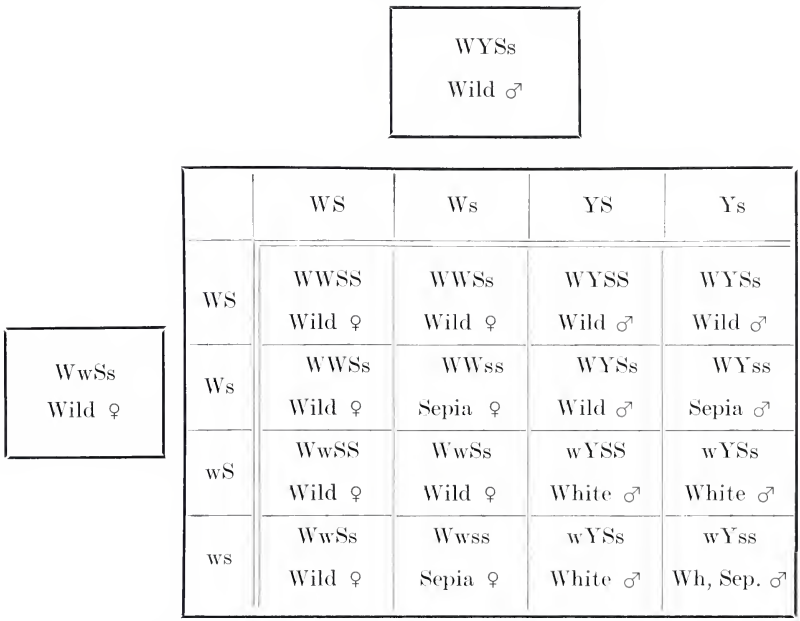


Fig. 2. A square showing the F_2 generation obtained by mating Wild F_1 males with Wild F_1 females. In this generation, the ratio of the offspring is 3 Wild ♂♂ : 6 Wild ♀♀ : 3 White ♂♂ : 1 Sepia ♂ : 2 Sepia ♀♀ : 1 White,Sepia ♂.

On the supposition that the White, Sepia flies fall in the Sepia phenotype, ten of the Sepia males, which appeared in the bottles, were mated to White virgins as soon as emergence had begun.

From figure 2, it is evident that only one combination, producing a true Sepia male, with the genotype WYss, is present in this genera-

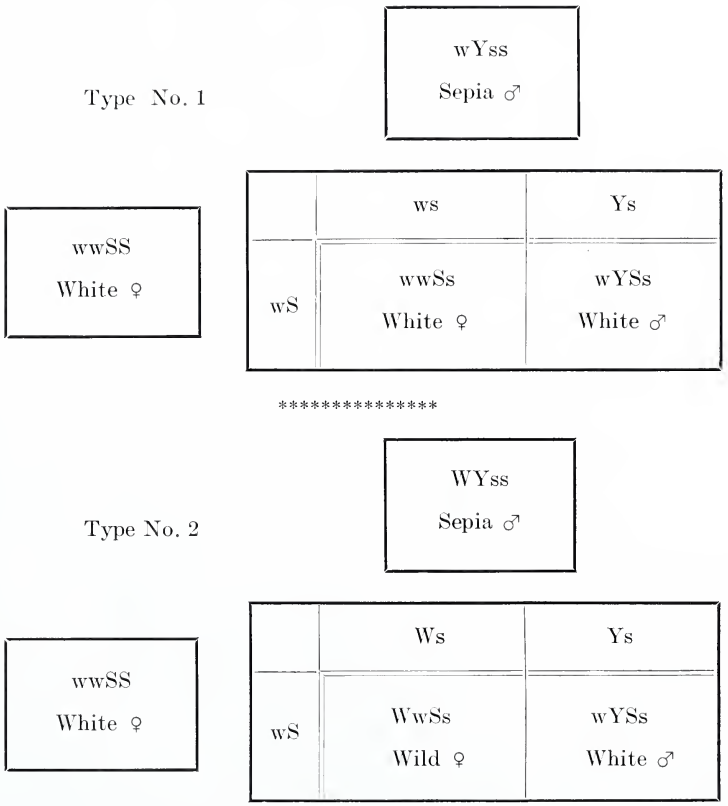


Fig. 3. Squares showing the results obtained when Sepia males of types No. 1 and No. 2 are mated with virgin Whites. In the case of the former type, all of the offspring are white-eyed, while the second type produces White males and Wild females.

tion. The White,Sepia male, having the genotype wYss, might also fall in the Sepia phenotype. Figure 3 shows the results that would be obtained when these two different types of males are mated to White virgins, in order to determine whether or not these sepia-eyed flies are carrying, in addition, the gene for White. It might be well to note, at this point, that all of the males tested throughout this experiment were removed from the mating bottles and saved separately until after their adult offspring had begun to appear. This was done in order to facilitate the production of a pure strain of White,Sepias, should an individual of that description appear—as determined by the kind of adult offspring

produced. Figure 3 clearly indicates how easily these two different types of flies may be differentiated from each other. Type No. 1, which is the kind of individual for which we are looking, would, when mated with the virgin White, give offspring all of which have white eyes. Type No. 2, the pure Sepia, will produce, under the same condition as above, offspring all the males of which have white eyes, and all the females of which are Wild, or red-eyed.

Only five of the ten Sepia males, mated as indicated above, produced offspring—the other five bottles being badly contaminated. In all five of these producing bottles, the offspring appeared as expected if the Sepia males were of the type No. 2 of figure 3. Since the ratio of the two types to each other was 1 : 1, it seemed that the first assumption about the eye-color of the combined characters (namely, that the White, Sepia male would fall in the Sepia phenotype) was at fault, unless the viability of the combination was so greatly reduced that they would not reproduce in the presence of a slight mold contamination.

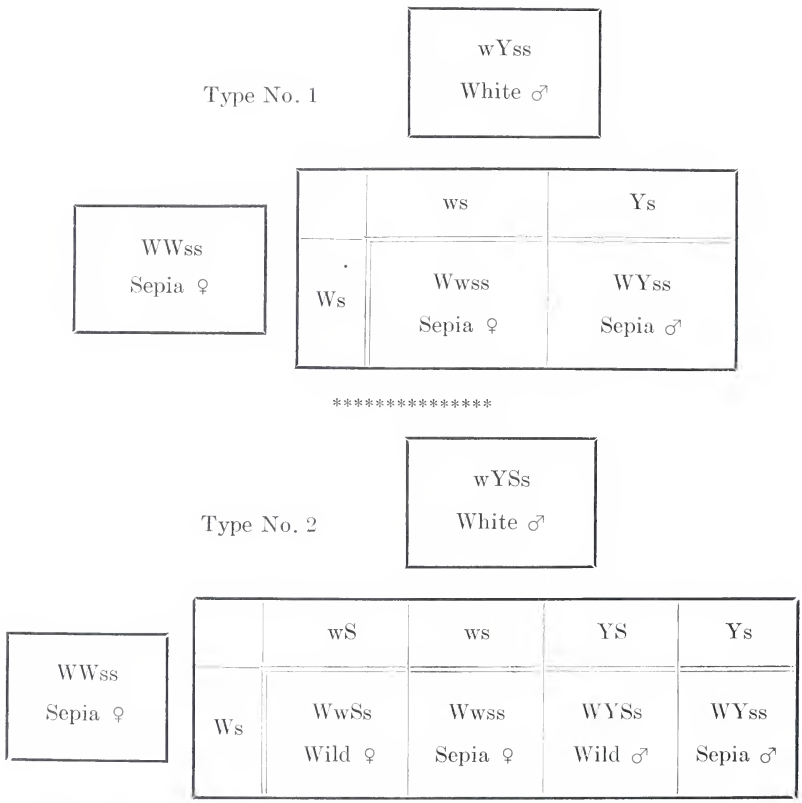


Fig. 4. Squares showing the results obtained when White males of types No. 1 and No. 2 are mated with virgin Sepias. In the case of the former type, all of the offspring are sepia-eyed, while the second type produces Wild males and females and also Sepia males and females.

Before it was time to discard the bottles which, theoretically at least, were producing White,Sepia individuals, it was noticed that the number of Sepia males produced was considerably below the expected number, while the number of White males was considerably higher than normal expectancy. Consequently, nineteen White males were removed from these bottles and mated to virgin Sepias.

In the case of the White males produced, there are two different possibilities with regard to genotypes. If it be assumed that the White, Sepia, individuals are White, there is one other possible combination. These different kinds of White males (see figures 1 and 4) will have the following genotypes: Type No. 1, the pure White,Sepia, wYss; type No. 2, the heterozygous White,Sepia, wYss; and type No. 3, a pure White with the same genotype as the original White male, wYSS. Figure 1 indicates the results obtained when the latter type is mated to a Sepia virgin; all of the offspring are Wild. The expected results, obtained when types No 1 and No. 2 are mated in the same way, are shown in figure 4. If the individual is a homozygous White,Sepia, all of his offspring will have sepia eyes. If, on the other hand, the White male is merely heterozygous for Sepia, Wild males and females and also Sepia males and females are produced in equal numbers. Again, it can be seen how easily the different genetic types of White males are determined, merely by mating them with virgin Sepias and observing their offspring. Here again, as was noted above, all of the males mated were saved until after their offspring had been observed long enough to determine the genetic constitution of the male parents.

Of the nineteen bottles in which the White males were mated with Sepia virgins, only four failed to produce offspring. Assuming that the White,Sepia flies fall in the White phenotype, it can be seen from figure 2 that the different genotypes of White males have the following ratio: 1 wYss : : 2 wYSs : 1 wYSS. Therefore, a greater number of these were mated than in the case of the sepia-eyed males, because only one-fourth of the White males would be expected to be of the White,Sepia type. Of these fifteen males which produced offspring, thirteen proved to have the genotype wYSs (type No. 2, figure 4), and one the genotype wYSS (male parent in figure 1); and only one proved to be a homozygous White,Sepia having the genotype wYss (type No. 1, figure 4). Since this last individual was the one for which search had been made, he was mated immediately to one of his virgin daughters, a sepia-eyed individual, for the purpose of producing a pure strain of flies of his type. Figure 5 depicts this latter cross, showing the offspring expected, White males and females and Sepia males and females in a ratio of approximately 1 : 1. The actual results agreed very closely with the expected ratio, as can be seen from the fact that, in this cross, there were 196 white-eyed individuals and 204 sepia-eyed individuals produced. Since all of these white-eyed flies were homozygous White,Sepias, some of the White males were mated with their virgin white-eyed sisters, thus establishing a strain which was homozygous for both White and Sepia eye-colors.

The next problem was to prove definitely whether the White,Sepia strain was homozygous for Sepia as well as for White. If it were, this

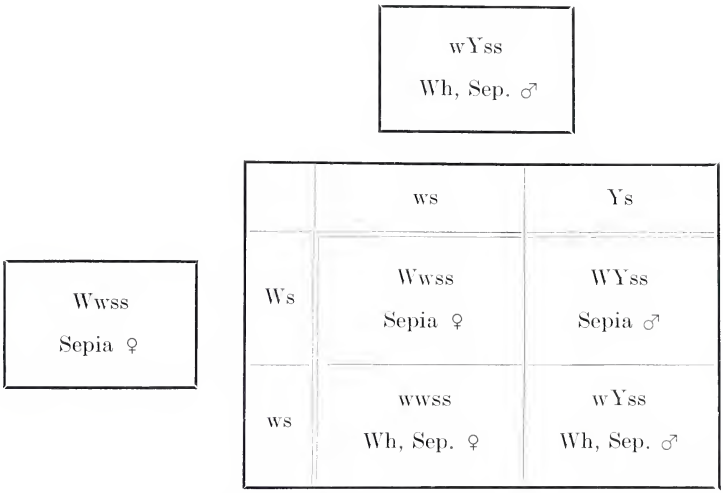


Fig. 5. The cross between the isolated White,Sepia male and one of his virgin daughters in the production of a pure strain of White,Sepias. All of the white-eyed flies produced in this generation are pure for both White and Sepia.

would indicate that the Sepia eye-color was completely masked by the White eye-color. Accordingly, two sets of matings were made. In the first, White,Sepia males were mated with virgin Sepias in pairs. The offspring were observed, and all were found to have sepia eyes. This conforms very nicely with the expected result for this cross and proves that the White,Sepia stock is homozygous for the Sepia factor. In the other set, White,Sepia virgins were mated with pure White males. All of the offspring, in this case, were white-eyed, thus proving that the above combination was also homozygous for White.

The accompanying table shows the actual results obtained in the F_2 generation: and, in addition, whether in the various ratios the White Sepia males are counted as a separate class, in the Sepia phenotype, or

TABLE 1. Actual Results and Expected Numbers Obtained in the F_2 Generation

		Wild		White	Sepia		Wh, Sep.
		♂	♀	♂	♂	♀	♂
Actual results		117	187	124	22	60	?
Exp.	1. 3:6:3:1:2:1	96	192	96	32	64	32
	2. 3:6:3:2:2:0	96	192	96	64	64	0
	3. 3:6:4:1:2:0	96	192	128	32	64	0

1. $X^2 = 13.266$ $P = 0.010069$
2. $X^2 = 40.701$ $P = 0.000018$
3. $X^2 = 8.223$ $P = 0.087$

in the White phenotype. If they are counted as a separate class, the ratio is 3:6:3:1:2:1; if in the Sepia phenotype it is 3:6:3:2:2:0. If, however, one counts them in the White phenotype, the ratio is 3:6:4:1:2:0. The X^2 method for determining the goodness of fit, when applied to the results expected from the above ratios, gave the following probabilities: 0.010069 for the 3:6:3:1:2:1 ratio, 0.000018 for the 3:6:3:2:2:0 ratio, and 0.087 for the 3:6:4:1:2:0 ratio. Since probabilities are considered acceptable when they fall within the arbitrarily set limits of 0.02 and 0.98, it is seen at once that the 3:6:4:1:2:0 ratio gives the best result, although even it is a little too low for an extremely good fit. The first two results, in fact, are below the lower limit within which a probability is acceptable. This then is a further indication that the White,Sepias had been counted in the class with the White males.

There are three lines of evidence all of which indicate that the White,Sepia individuals are white-eyed instead of sepia-eyed, and that Sepia is completely masked by White. They are: First, the evidence obtained from the matings used in the isolation of the White,Sepia male; second, the evidence from confirmatory matings of flies from the new White,Sepia strain with White and Sepia individuals obtained from the respective stock strains; and third, the evidence from the use of the X^2 method for determining the goodness of fit when applied to the combined data obtained from mating two of the heterozygous Wild offspring, resulting from the original cross of the White male with the Sepia female.

For his kind assistance and advice in developing this project and in editing this paper, I wish to express my deep appreciation to Mr. S. A. Rifenburgh, instructor in Zoology, Purdue University.

BIRDS OF TIPPECANOE COUNTY, III

Louis A. Test and Frederick H. Test, West Lafayette

92. *Antrostomus Vociferus Vociferus* (Wilson). Eastern Whip-poor-will. (417.) Formerly very common and still not uncommon in the more extensive and less accessible woodlands where it readily makes itself known at night, but is rarely seen. Summer resident and migrant. Probably arrives about the first of May. Our earliest record is April 25, 1902 from the records of the Purdue Bird Club. Fall records are lacking, due probably to the fact that the bird is less noisy at this time and is seldom seen.

93. *Chordeiles Minor Minor* (Forster). Eastern Nighthawk. (420.) A common summer resident and regular migrant, the nighthawk is conspicuous in the evenings pursuing its insect prey in both town and country. It seems most abundant during the fall migrations in August and September, when large flocks are often seen in the air at sunset. The nighthawk nests commonly in cities, laying its eggs on the flat graveled roofs of tall buildings. During the summer of 1920 a nest was found on the roof of the Purdue University Armory and several photographs taken of it. These birds usually arrive early in May, but we have two April dates, April 26, 1904 (Purdue Bird Club) and April 14, 1929 (M. W. Gardner). In the fall the majority leave in September but there is one late date, Nov. 21, 1928 (D. R. Burtsfield). The nighthawk is unquestionably very beneficial because of its destruction of insect life.

94. *Chaetura Pelagica* (Linnaeus). Chimney Swift. (423.) Abundant migrant and summer resident throughout the county. In spring and fall they often congregate in large flocks to roost in a particular chimney. They usually arrive in the spring about the middle of April and leave about the end of the first week in October. Early and late dates of first arrival are April 7, 1925, and April 21, 1932. Early and late dates of departure are October 6, 1931, and October 21, 1925. Banding records show that these birds return to the same locality year after year. An interesting record is that of a chimney swift banded here on Sept. 6, 1929, and captured Oct. 5, 1930, at Chattanooga, Tennessee, by Wyman R. Green.

95. *Archilochus Colubris* (Linnaeus). Ruby-throated Hummingbird. (428.) A common summer resident usually arriving early in May and leaving toward the end of September. Early and late dates of arrival are April 30, 1902 (Purdue Bird Club) and May 15, 1931. Early and late dates of departure are September 20, 1928 (M. W. Gardner) and September 28, 1931. The hummingbird nests commonly throughout the county, usually in thick woods, but is not particular as to the species

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

of tree chosen for its nest. We have taken nests from oak, hickory, hard maple and sycamore. Hummingbirds are fond of congregating around jewel weed in the late summer.

96. *Megaceryle Alcyon Alcyon* (Linnaeus). Eastern Belted Kingfisher. (390.) The Kingfisher is a common summer resident along the streams of the county, and apparently a few remain throughout the winter, at least occasionally. No stream or pond is complete without its pair of kingfishers. The birds become common in March and the most seem to leave in October. Winter dates are February 22, 1928, and December 17, 1904 (G. R. Jenkins).

97. *Colaptes Auratus Luteus* Bangs. Northern Flicker. (412a.) The flicker is an abundant summer resident, and a few remain throughout the winter. Whether these winter birds are really all year residents or merely birds which nested farther north has not been determined. In the winter one of their principal foods is hackberries. The flickers usually become common early in March. It will be interesting to observe what effect the rapid increase in the starling will have upon the nesting of flickers.

98. *Centurus Carolinus* (Linnaeus). Red-bellied Woodpecker. (409.) This beautiful woodpecker is not very common in the county but is more abundant farther south. It is a resident, some nesting in the county, but is somewhat more common in the winter when they occasionally are seen in the towns. It is usually met with in the heavily wooded areas, especially during the nesting season. As the woods have disappeared this desirable bird has become less common, which is to be regretted, as it is both handsome and beneficial.

99. *Melanerpes Erythrocephalus* (Linnaeus). Red-headed Woodpecker. (406.) This striking and familiar bird is a common summer resident and, locally, a winter resident, at least, occasionally. The winter of 1928-1929 they were particularly common near Lafayette and were seen on several occasions in various localities. In the winter they are concentrated in rather restricted areas, usually in oak groves. In the spring they become common about the middle of April and begin nesting late in May. The past few years the birds have seemed less common than formerly. As the starlings have become more abundant and appropriated the woodpecker holes as nesting sites it is possible some are unable to raise their customary broods or they have been driven to other localities not much frequented by the starlings. It is also of interest that the red-headed woodpecker seems to be killed more frequently by automobiles than any other species of bird, but it seems doubtful if this occurs often enough to make any appreciable decrease in the bird population.

100. *Sphyrapicus Varius Varius* (Linnaeus). Yellow-bellied Sapsucker. (402.) The yellow-bellied sapsucker is a regular and common migrant in both spring and fall, and occasionally one is seen in the winter. There are no summer records, and there is no evidence that it nests in the county. In the spring it is most common early in April and

in the fall, in late September and early October. Early and late spring dates are March 23, 1928 (M. W. Gardner) and May 1, 1932. Early and late fall dates are September 22, 1928 (D. R. Burtsfield) and October 25, 1924. Winter dates are January 5, 1906, and January 3, 1929.

101. *Dryobates Villosus Villosus* (Linnaeus). Eastern Hairy Woodpecker. (393.) The hairy woodpecker is not very common in Tippecanoe county but seems to be a permanent resident wherever found, though it is more frequently seen in the spring and fall. This bird sometimes comes into the towns but is more often seen in the heavily wooded areas than near habitations. We have no records of any nest actually being found. There are skins from the vicinity of Lafayette in our collections.

102. *Dryobates Pubescens Medianus* (Swainson). Northern Downy Woodpecker. (394c.) The downy woodpecker is a common resident everywhere throughout the county, frequenting not only dense and open woods but orchards and towns. In general, many seem to frequent the towns in the winter and return to the woods during the nesting season, though this movement can hardly be said to be universal. Banding records indicate that the downy woodpecker is a permanent resident, the same individuals remaining the year round. Skins and eggs taken in the county are in our collections.

103. *Tyrannus Tyrannus* (Linnaeus). Eastern Kingbird. (444.) This nervous flycatcher is a most characteristic and common sight of the road sides at all times during the summer. It arrives during the latter part of April and first part of May, our earliest date being April 24, 1904 (Purdue Bird Club). Usually two broods are raised, and the southward migration is started in the middle of September. A set of eggs taken June 7 had incubation advanced. For the past six years a pair of kingbirds has nested in an elm in front of the writer's home at the edge of West Lafayette where their pugnacious dispositions have seemingly had no effect on the rest of the neighborhood bird life. One of the adults was caught and banded when it flew to the ground and fed on bread crumbs beneath a drop trap. Indications are that this species has increased in numbers, as it prefers orchards and cleared land to heavy timber.

104. *Myiarchus Crinitus Boreus* Bangs. Northern Crested Flycatcher. (452a.) Arriving at the same time as the last species, our earliest record being for April 24, 1902, and 1904 (Purdue Bird Club) this loud-voiced flycatcher makes his presence known much more often by sound than by sight. He is a common summer resident, also leaving early in the fall. As deep woods are the favorite habitat, there has probably been a decrease in numbers as the land has been cleared, although individuals may often be seen in West Lafayette. Two sets of eggs, taken June 11 and June 28, with incubation begun, were both taken from nests containing pieces of snake skin.

105. *Sayornis Phoebe* (Latham). Eastern Phoebe. (456.) This, our earliest flycatcher to arrive in the spring, is also the last species to leave, extreme dates of its stay being March 18, 1893, 1903 and 1927,

and Oct. 12, 1932. The majority of the birds are here by the first week in April and nesting begins soon after, downy young having been found early in May (D. R. Burtsfield). Nesting birds can be found wherever there is a suitable structure against which to build the nest near water. The twitch of a Phoebe's tail is a sure field mark. Rarely, a set of eggs is found in which the usual pure white is sparingly spotted with reddish-brown. No perceptible change in numbers has been noticed in the Phoebe population over the last 40 years.

106. *Empidonax Flaviventris* (Baird and Baird). Yellow-bellied Flycatcher. (463.) Seemingly a rare migrant, as we have only two definite records, May 22, 1931, and August 20, 1932. It is probably a more regular migrant than these records indicate, possibly overlooked because of its secretive habits.

107. *Empidonax Virescens* (Vieillot). Acadian Flycatcher. (465.) A fairly common migrant and summer resident. Bottoms of ravines and river bottoms are the favorite habitat of this unsuspecting bird, which is usually first located by its single short note. The nest can always be recognized by the debris hanging from it and from its position near the end of a limb and not far from the ground. The only dates we have are spring records, ranging from May 4, 1902 (Purdue Bird Club), to May 26, 1931.

108. *Empidonax Trailli Trailli* (Audubon). Alder Flycatcher. (466a.) Not much is known about the present status of this species in Tippecanoe County, but it is a migrant and summer resident. The only three records available are April 28, 1897, May 10, 1903 (Purdue Bird Club), and May 24, 1929, which are sight records, and a set of 3 eggs taken July 5, 1892, on the outskirts of West Lafayette. The bird was shot for identification.

109. *Empidonax Minimus* (Baird and Baird). Least Flycatcher. (467.) A common migrant and probably a summer resident although we have no nesting records for it. Spring dates extend from May 2, 1902 (Purdue Bird Club), to May 20, 1927 (M. W. Gardner), and fall dates from September 13 to 25 (both by D. R. Burtsfield). This species can be found almost any time during spring migration in fairly open woods and scrub timber, where its sharp "che-bec" readily identifies it.

110. *Myiochanes Virens* (Linnaeus). Eastern Wood Pewee. (461.) This common flycatcher, so characteristic of the more or less open woods, is a considerably later arrival than the phoebe, which it so closely resembles. Our earliest date is April 28, 1904 (Purdue Bird Club), but the majority of the birds usually arrive during the first two weeks in May. The wood pewee also leaves early, most of them having left by early October. Wood pewees breed in the county in considerable numbers. Eggs and skins taken in the county are in our collections.

111. *Otocoris Alpestris Alpestris* (Linnaeus). Northern Horned Lark. (474.) This is a form upon which more work must be done before its status in this area can be stated. At present we have no definite

records for it, which is probably due to observers confusing it with the next form. In fact, it would be nearly impossible to make an accurate determination without the bird in one's hand. As its winter range includes all of northern Indiana it undoubtedly occurs here as a winter resident.

112. *Otocoris Alpestris Praticola* Henshaw. Prairie Horned Lark. (474b.) All the horned lark records we have are referred to this form because of the difficulty in distinguishing between it and the preceding form, and this bird nests commonly in the county and is known to be a permanent resident in this part of the country. Due to the horned lark's habit of nesting very early in the spring, young able to fly have been found on April 25, 1893. This bird seems to have decreased in numbers here in the past 40 years, possibly because much of this county was formerly prairie, and a larger area is now cultivated in such a way as to furnish unsuitable nesting sites. In the 1890's several nests were found on the Purdue campus. Skins and eggs taken in the county are in our collection.

113. *Iridoprocne Bicolor* (Vieillot). Tree Swallow. (614.) Apparently the tree swallow is not common in the county though it undoubtedly occurs as a migrant, and a few nest. The only locality where they have been observed nesting is in dead willow trees at the Willow Pond about 6 miles north of Lafayette. They have been observed nesting there in June, 1930, July, 1931, and July, 1932. The earliest date of arrival is March 29, 1932, and a late summer date is August 8, 1932.

114. *Riparia Riparia Riparia* (Linnaeus). Bank Swallow. (616.) Migrant and common summer resident along the streams wherever suitable banks are found for their nesting burrows. Here they often congregate in large numbers along with the less common rough-winged swallow. The bank swallow usually arrives in April and begins nesting in May. An exceptionally early date is March 20, 1897, and an average date would be April 27 (1927).

115. *Stelgidopteryx Ruficollis Serripennis* (Audubon). Rough-winged Swallow. (617.) The rough-winged swallow does not seem to be as common as the last species but is a regular migrant and breeds. It is found associated with the bank swallow to some extent. It probably is very often confused with the bank swallow and as a result there are few migration dates. A spring date is April 30, 1932.

116. *Hirundo Erythrogaster* Boddaert. Barn Swallow. (613.) The barn swallow is a common migrant and summer resident. Seemingly, it is not so common as 30 or 40 years ago but still nests commonly in suitable barns. It was found nesting at Scipio's at the same time as the cliff swallows. The spring migrants usually arrive about the middle of April. An early date of arrival is April 11, 1931, and a late date May 4, 1924. The only fall record is September 9, 1931.

117. *Petrochelidon Albifrons Albifrons* (Rafinesque). Northern Cliff Swallow. (612.) This interesting swallow formerly was fairly

common in the county but is now quite rare. It is a migrant and summer resident, seeming to arrive early in May, but we have few definite dates. May 9, 1931, five were seen. The last nesting colony observed in the county was on the farm of O. A. Scipio on the river road six miles south of Lafayette in the summer of 1928. Here there was a colony with 30 nests under the eaves on the south side of the barn. The birds did not return in 1929 perhaps because the barn was painted that spring and the old nests destroyed. A set of eggs is in our collection taken from a nest under the eaves of a barn in West Lafayette, June 20, 1890.

118. *Progne Subis Subis* (Linnaeus). Purple Martin. (611.) The purple martin is a migrant and common summer resident wherever they find suitable nesting places, usually preferring the martin boxes put up for them. Apparently only one brood is reared in a season. They usually begin to arrive late in March and are common early in April. In the fall they leave in August or early September. Before leaving they collect in large flocks, usually on the telephone wires where it would seem as if their combined weights must surely break the wire. Early dates of arrival and late dates of departure are March 21, 1925, and September 9, 1931.

119. *Cyanocitta Cristata Cristata* (Linnaeus). Northern Blue Jay. (477.) The blue jay is a common resident, being one of the characteristic birds of the county both winter and summer. They nest commonly in the towns as well as in the country. They come readily to feeding stations and do not appear to interfere seriously with other birds. Banding records show that at least some individuals are residents the year round and generally are restricted to rather limited areas. There is no direct evidence that any of the birds migrate, though they are frequently seen in small flocks in the fall and winter. All banding returns have been within a mile of the place where the bird was originally banded. Both eggs and skins taken at Lafayette are in our collection.

120. *Corvus Brachyrhynchos Brachyrhynchos* Brehm. Eastern Crow. (488.) The crow is one of the common and characteristic birds of the county. A generally distributed resident, it nests commonly in the early spring, eggs being laid about April 1, and the young leaving the nest late in May. There is a large crow roost just south of the southern edge of the county, not far from road 52, and morning and evening large numbers can be seen flying over road 52. The increase in population and destruction of our forests seem to have had little effect upon the crow, and the numbers seem approximately the same as 40 years ago. They seem to adjust themselves well to changing conditions.

121. *Penthestes Atricapillus Atricapillus* (Linnaeus). Black-capped Chickadee. (735.) The black-capped chickadee nests in the county and is probably a resident though to what extent the individuals remain in the same locality for the entire year is not known. This chickadee is not common anywhere in this area and in some places is quite rare. It seems to have decreased greatly in the past 25 years for it formerly was fairly common throughout the county.

122. *Penthestes Carolinensis Carolinensis* (Audubon). Carolina Chickadee. (736.) There seems to be some confusion as to the relative abundance of this and the preceeding species, so that it is very difficult to estimate the relative abundance of the two species. A specimen which was undoubtedly P. C. Carolensis was secured in the northern part of the county January 23, 1931. Whether it was a more or less accidental occurrence or is more common than has been assumed has not yet been determined, but unquestionably both species should be included in the birds of the county. Both probably breed here.

123. *Baeolophus Bicolor* (Linnaeus). Tufted Titmouse. (731.) The tufted titmouse is a common resident of the county and nests in considerable numbers. It is found both in the towns and the less settled wooded districts, but is more common in the towns during the winter and early spring. The numbers of titmice do not seem to have changed materially in the past 40 years.

124. *Sitta carolinensis carolinensis* Latham. White-breasted Nuthatch. (727.) The white-breasted nuthatch breeds in the county and is a common resident. This bird is more abundant during the winter than in the nesting season and at that time comes commonly into the towns. They are usually seen in pairs during the winter and perhaps remain mated during the entire year. The abundance of this species does not seem to have changed appreciably during the past 40 years.

125. *Sitta canadensis* Linnaeus. Red-breasted Nuthatch. (728.) This nuthatch is less common than the preceding. It does not nest in the county and is seen mostly during the spring and fall migrations, usually in April and October. Early and late spring dates are March 20, 1902 (Purdue Bird Club), and May 16, 1926 (M. W. Gardner). Two fall dates are September 25, 1902 (Purdue Bird Club), and October 25, 1924. Skins are in our collection.

126. *Certhia familiaris americana* Bonaparte. Brown Creeper. (726.) The brown creeper is a fairly common migrant both spring and fall, and some apparently are winter residents. There is no record of its nesting in the county, and all individuals seem to leave before May 1. The earliest fall date is September 26, 1928 (D. R. Burtsfield), and latest spring date is April 30, 1904 (Purdue Bird Club). Between September and April there are records for every month except December. They are most abundant in April and October.

127. *Troglodytes aedon aedon* Vieillot. Eastern House Wren. (721.) The house wren is a common summer resident and migrant all over the county, preferring the neighborhood of houses for its nesting sites. They usually arrive about the middle of April and leave in September. They are in full song on arrival. The earliest spring date of arrival is April 11, 1930, and the latest, May 4, 1924. The latest fall date is September 29, 1931. They become common within two or three days of the first arrival.

128. *Nannushiemalis hiemalis* (Vieillot). Eastern Winter Wren. (722.) The winter wren does not nest in the county and is found only

as a migrant and winter resident. It is not common and is found mostly in the more heavily wooded sections though sometimes is seen in towns, and around houses. The earliest fall date is September 13, 1894, and there are a few December dates. A late spring date is April 26, 1904 (Purdue Bird Club).

129. *Thryomanes bewicki bewicki* (Audubon). Bewick's Wren. (719.) The Bewick's wren is a regular migrant and summer resident but is far less common than the house wren, as it is a more southern species. It seems to be extending its range northward. The first report from the county was in 1891, when one nested in a mail box in West Lafayette. They seem to be slowly increasing and a number nest in this locality every summer. A few years ago a pair built a nest in an old lantern hanging on the porch of a farm house. The Bewick's wren arrives from two to four weeks earlier than the house wren and is usually in full song when it arrives. Early and late dates of arrival are March 16, 1927, and April 11, 1931. The only fall record is September 23, 1927.

130. *Thryothorus ludovicianus ludovicianus* (Latham). Carolina Wren. (718.) This is one of the wrens which seems to have decreased in number in the past 40 years. While never abundant this far north it formerly was not uncommon but is now rarely seen. It is usually noticed in spring and early summer but is probably a resident, and a few nest in suitable localities, preferably near the water courses. A set of 5 eggs is in our collection taken July 15, 1893, near the site of the State Soldiers' Home, north of Lafayette.

131. *Telmalodytes palustris dissaeptus* (Bangs). Prairie Marsh Wren. (725d.) This wren is not common but is occasionally seen throughout the county wherever suitable marshes occur. There is no authentic record of its nesting though it may do so, but summer records are lacking after May 22 (1904, Purdue Bird Club). Most of the records are for fall. These birds were seen fairly commonly a number of times at Headley's Lake in September, 1932, and specimens collected.

132. *Cistothorus stellaris* (Naumann). Short-billed Marsh Wren. Was considered quite rare in the county until the past two years when it has been seen in the late summer and fall in some numbers at Headley's Lake. They have been seen only in the late summer and fall and very possibly nest though there are no records of its doing so. The earliest date is July 30, 1932, and the latest October 19, 1932, both at Headley's Lake.

133. *Mimus polyglottos polyglottos* (Linnaeus.) Eastern Mockingbird. (703.) The mockingbird seemingly is a regular though rather rare resident, and there are a number of nesting records. Some have been seen in restricted localities all winter, though they seem more common in the summer. Thirty years ago mocking birds were nesting in the south part of the county and more recently nests have been found in other places. D. R. Burtsfield reports the following nesting records: Nest and two eggs, 10 miles north of West Lafayette on county farm

road, May 27, 1928; nest with one egg and one young, June 3, 1928, near Granville Bridge; three downy young in nest, July 13, 1930, a few miles west of town. Probably the mockingbird is slightly more common in the county now than thirty years ago.

134. *Dumetella carolinensis* (Linnaeus.) Catbird. (704.) The catbird is an abundant summer resident and nests commonly in the neighborhood of houses where it prefers the dense shrubbery. It usually arrives late in April and leaves early in October. It becomes common soon after the first arrivals make their appearance. Early and late dates of arrival are: April 17, 1902 (Purdue Bird Club), and May 4, 1928 (M. W. Gardner). A late fall date is October 9, 1928 (D. R. Burtsfield).

135. *Toxostoma rufum* (Linneaus.) Brown Thrasher. (705.) Like the preceding species the brown thrasher is an abundant summer resident of the county wherever thickets or shrubbery are found. It nests commonly. The birds first make their appearance about April first and are soon in full song. They leave early in October. Early and late spring dates are March 25, 1893 and 1903 (Purdue Bird Club), and April 17, 1902 (Purdue Bird Club). A late fall date is October 22, 1931.

136. *Turdus migratorius migratorius* Linnaeus. Eastern Robin. (761.) The robin is an abundant summer resident, and some few always spend the winter in the county; so that there are records for every month in the year. They usually become common late in February and begin nesting early in April. Three broods are generally raised in a season. In the fall they collect more or less in flocks, and the most of them have left for the south by early November. Birds that nested in the county have been taken in Florida during the winter.

137. *Hylocichla mustelina* (Gmelin.) Wood Thrush. (755.) The wood thrush is a common migrant and summer resident, nesting commonly in the wooded sections. This bird usually arrives about the first of May and leaves in September or early October. Early and late dates of arrival are April 20, 1902 (Purdue Bird Club), and May 11, 1929 (M. W. Gardner.) A late fall date is October 29, 1932, when one was seen at Camp Tecumseh just outside the north line of Tippecanoe County.

138. *Hylocichla guttata faxoni* (Bangs and Penard.) Eastern Hermit Thrush. (7596.) The hermit thrush is a fairly common migrant both spring and fall, apparently more common in the spring. In the spring they usually arrive late in March or early in April and the most have left by the last of the month. Early dates of arrival and late dates of departure are March 21, 1927, and May 4, 1929 (D. R. Burtsfield). Fall dates are October 3, 1928, and October 19, 1928, both by D. R. Burtsfield.

139. *Hylocichla ustulata swainsoni* (Tschudi.) Olive-backed Thrush. (758a.) The olive-backed thrush is probably the most abundant of the migrant thrushes in the county and is found during both spring

and fall. It is usually quite common in May and again in September. Early and late spring dates are April 27, 1929 (D. R. Burtsfield), and June 3, 1929. A late fall date is September 21, 1929 (D. R. Burtsfield). This thrush does not seem to have decreased in numbers in the past 40 years.

140. *Hylocichla minima aliciae* (Baird.) Gray-cheeked Thrush. (757.) This thrush is seen in the county only as a migrant in May and September. While fairly common, it is not so abundant as the preceding species. It seems to be holding its own in numbers in spite of the disappearance of much of our forested areas. Early dates of arrival and late dates of departure in spring are May 1, 1904 (Purdue Bird Club), and May 29, 1925. Fall dates are September 6, 1928 (D. R. Burtsfield), and October 2, 1926.

141. *Sialia sialis sialis* (Linnaeus). Eastern Bluebird. (766.) The bluebird is one of the earliest of the spring migrants and is a moderately common summer resident, though probably not so common as formerly. It arrives in February or early March and leaves in late October or November. Early and late dates of first arrival are February 5, 1927 and 1931 (C. L. Porter), and March 19, 1926. A late fall date is November 22, 1931. Because bluebirds arrive here with the first days of warm weather, cold snaps in the late spring always take quite a toll. The results of a heavy blizzard are noticeable for the following two or three years in the scarcity of bluebirds.

142. *Palioptila caerulea caerulea* (Linnaeus). Blue-gray Gnatcatcher. (751.) The blue-gray gnatcatcher is a fairly common migrant and not uncommon summer resident. Early and late dates of arrival are April 17, 1904 (Purdue Bird Club), and May 15, 1929. Skins, nests and eggs taken in the county are in our collection.

143. *Regulus satrapa satrapa* (Lichtenstein). Eastern Golden-crowned Kinglet. (748.) The golden-crowned kinglet is a regular and common spring and fall migrant and probably winter resident in some numbers. It is usually most common in March, April and October. Our latest spring date is May 11, 1904 (Purdue Bird Club), and the earliest fall date October 3, 1932. Winter dates are December 27, 1929, January 3, 1925, and February 4, 1904 (Purdue Bird Club). Our collection contains skins taken in this county. This kinglet has probably slightly decreased in the past 30 years.

144. *Corthylio calendula calendula* (Linnaeus). Eastern Ruby-crowned Kinglet. (749.) Like the former species this kinglet is not quite so common as formerly but is still a common migrant and possibly a winter resident. It seems more common in spring than fall, particularly so during April. The latest spring date is May 8, 1932. The earliest fall date is October 12, 1932. A winter date is December 30, 1929 (D. R. Burtsfield).

145. *Anthus spinoletta rubescens* (Tunstall). American Pipit. (697.) The Pipit formerly was a fairly common spring migrant in

the county, frequenting the meadows and open prairie, but now seems to be rare. We have obtained no records for the last ten years. An early spring record is March 18, 1903, and a late one May 8, 1904, both by the Purdue Bird Club. Skins of specimens taken in the county are in our collection.

146. *Bombycilla cedrorum* (Vieillot). Cedar Waxwing. (619.) While the cedar waxwing may be considered fairly common it is of irregular occurence, sometimes being common for a few weeks then absent altogether for some months. It nests, some seasons fairly commonly and others apparently not at all. There are records for most of the months of the year, and there seems to be no one time in which it can be said to be most abundant. It certainly deserves to be called a nomad. Skins and eggs taken in the county are in our collection. This species seems about as common as formerly.

147. *Lanius borealis borealis* (Vieillot). Northern Shrike. (621.) Formerly the northern shrike was not uncommon as a winter visitor but seems to be quite rare in the past 25 years, and there have been no records in the past few years. Skins of specimens taken in the county are in our collection. Two dates are February 3, 1894 and February 28, 1904 (Purdue Bird Club).

148. *Lanius ludovicianus migrans* (Palmer). Migrant Shrike. (622e.) The migrant shrike is a moderately common migrant and summer resident, nesting regularly, especially in the prairie regions. The birds usually arrive in March and are nesting in April (nest with eggs April 23, 1932). Osage orange hedges are favorite nesting sites. Early and late dates of arrival are March 14, 1903 (Purdue Bird Club), and April 5, 1925.

149. *Sturnus vulgaris vulgaris* (Linnaeus). Starling. (493.) The first record of the starling in Tippecanoe County is May 12, 1926 when two were seen in West Lafayette. The next record is October 31, 1926. Whether any nested in the county that year is not known, but they were reported a mile south of Lafayette January 1, 1927, and on January 4 were found at the farm of O. A. Scipio, 6 miles south of Lafayette. They were nesting at Scipio's May 27, 1927, and now nest commonly in the county. The starling is becoming abundant and is now found every month of the year. Some are undoubtedly residents but what proportion is resident and what is migratory has not been determined. Except at nesting time they are usually in flocks varying in size from a few individuals to several hundred. These flocks are often associated with flocks of bronzed grackles, red-winged blackbirds and cowbirds, particularly at roosting time. As yet the starling here is not a bird of the cities, being found mostly in the country and only coming into town to roost in the parks or shade trees. Large numbers roost in farm buildings in the winter. Their effect upon the native bird life is not marked as yet.

150. *Vireo griseus griseus* (Boddaert). White-eyed Vireo. (631.) The white-eyed vireo is apparently rare in this county as we have but

two records, April 28, 1894, and April 24, 1904 (Purdue Bird Club). It is not unlikely that it nests in the county but we have no records.

151. *Vireo flavifrons* (Vieillot). Yellow-throated Vireo. (628.) The yellow-throated vireo is not an uncommon migrant, and a few nest in the county. Apparently it was formerly more common than at present. It is most common in April and early May. Early and late spring dates are April 24, 1904 (Purdue Bird Club), and May 24, 1930 (M. W. Gardner).

152. *Vireo solitarius* (Wilson). Blue-headed Vireo. (629.) The blue-headed vireo is a rare migrant, and there are few records though they are scattered over 40 years. All are spring records. A recent and late date is May 24, 1929.

153. *Vireo olivaceus* (Linnaeus). Red-eyed Vireo. (624.) This is the most common of the vireos and is found commonly throughout the county during the migrations and during the nesting season, frequenting the heavily wooded sections. It is more often heard than seen, as it keeps well concealed in the foliage. The first birds usually arrive late in April or early in May. Early and late spring dates of arrival are April 24, 1897, and May 12, 1929. A fall date is September 4, 1902 (Purdue Bird Club).

154. *Vireo philadelphieus* (Cassin). Philadelphia Vireo. (626.) The Philadelphia vireo is a rare migrant, our early record being September 9, 1932, when a single specimen was taken on the Wea Creek about two miles south of Lafayette, along State Road 43. The specimen, the skin of which is in our collection, was an adult male.

155. *Vireo gilvus gilvus* (Vieillot). Eastern Warbling Vireo. (627.) The warbling vireo is a fairly common migrant and summer resident, often nesting in the shade trees of the towns as well as in the country. This species is much more frequently heard than seen. Early individuals usually arrive in May. Early and late dates of arrival are April 28, 1896, and May 8, 1927 (M. W. Gardner). This vireo is possibly slightly less common than formerly.

156. *Mniotilta varia* (Linnaeus). Black and White Warbler. (636.) The black and white warbler is a common migrant and has been found nesting in the wooded ravines along the Wabash river north of Lafayette. This early warbler usually arrives late in April or early in May and leaves in September. Early and late dates of arrival are April 18, 1896, and May 12, 1929 and 1931. Late fall dates are September 22, 1928, '29, '30. Skins and eggs are in our collection. This species seems about as common as formerly.

157. *Protonotaria citrea* (Boddaert). Prothonotary Warbler. (637.) The prothonotary warbler is a rare bird in the county, and there are few records. It probably nests, as indicated by a few summer records. Our only dates are April 30, 1927, May 15, 1929, and three June records. One was seen on an island in the Wabash River at Ross Camp, June 19, 23, 25, 1930, by D. R. Burtsfield.

158. *Helmitheros vermivorus* (Gmelin). Worm-eating Warbler. (639.) The worm-eating warbler is not a common species but is a migrant, and a few probably nest. It seems to prefer the heavily timbered ravines near the river. Early and late spring dates are May 8, 1897, and May 29, 1904 (Purdue Bird Club).

159. *Vermivora chrysoptera* (Linnaeus). Golden-winged Warbler. (642.) The golden-winged warbler seems to be quite rare as we have only two records, April 24, 1897, and May 14, 1929. There are no records of its nesting.

160. *Vermivora pinus* (Linnaeus). Blue-winged Warbler. (641.) The blue-winged warbler seems to be less common than formerly when it nested not uncommonly in the county. It seems to prefer the heavy second growth near the edge of the timber. Early and late spring dates are May 3, 1902, and May 20, 1904, both by the Purdue Bird Club. Skins from the county are in our collection.

161. *Vermivora peregrina* (Wilson). Tennessee Warbler. (647.) This is one of the most common warblers during the migration season but is often overlooked because it is inconspicuous. This species is most abundant about the middle of May and remains with us for only a week or two. Early and late dates are May 6, 1928, and May 25, 1929. A late fall date is October 5, 1929.

162. *Vermivora celata celata* (Say). Orange-crowned Warbler. (646.) This is one of the rarest of our warblers and we have but two sight records. These dates are May 16, 1903 (Purdue Bird Club), and May 13, 1931. A single individual was seen on the outskirts of West Lafayette on the latter date.

163. *Vermivora ruficapilla ruficapilla* (Wilson). Nashville Warbler. (645.) Nashville warblers are fairly common migrants, being more frequently reported in the spring than fall. They are most abundant about the middle of May. Early and late spring dates are April 26, 1902 (Purdue Bird Club), and May 25, 1929. Two fall dates are September 23, 1902 (Purdue Bird Club), and September 29, 1931.

164. *Compsothlypis americana pusilla* (Wilson). Northern Parula Warbler. (648a.) This is one of the rarer warblers in the county, and there are few records for it, all for the spring migrations. The earliest date is April 28, 1893, and the latest May 16, 1929. These are both sight records.

165. *Dendroica aestiva aestiva* (Gmelin). Eastern Yellow Warbler. (652.) The yellow warbler is a fairly common migrant and summer resident. Formerly it nested commonly in the county but seems to be less common at present. Early arrivals usually come late in April and begin nesting late in May. Early and late dates of arrival are April 26, 1902 (Purdue Bird Club), and May 16, 1930 (M. W. Gardner).

166. *Dendroica magnolia* (Wilson). Magnolia Warbler. (657.) The magnolia warbler is a common migrant but does not nest. It usually

arrives during the first half of May and leaves late in the same month. Early spring dates of arrival and late dates of departure are May 4, 1902 (Purdue Bird Club), and May 26, 1931. Early and late fall dates are September 15, 1931, and October 5, 1929.

167. *Dendroica tigrina* (Gmelin). Cape May Warbler. (650.) This is not a common species but some are seen almost every year during the spring migrations, usually in May. Occasionally they appear to be fairly common for a day or two. An early spring date is April 28, 1896, and a late date is May 16, 1926. We have no fall records. Skins of individuals taken in the county are in our collection.

168. *Dendroica caerulescens caerulescens* (Gmelin). Black-throated Blue Warbler. (654.) This species is not a very common one but can hardly be called rare. It is a migrant and does not nest. It usually arrives early in May and leaves in the latter half of that month. Early and late dates are April 25, 1902 (Purdue Bird Club), and May 21, 1930 (M. W. Gardner). The black-throated blue warbler seems to prefer the more heavily wooded districts and possibly is less common than formerly.

169. *Dendroica coronata* (Linnaeus). Myrtle Warbler. (655.) This, the most abundant of our migrating warblers, is abundant in both spring and fall migrations but does not nest. It is usually the earliest of the warblers to arrive in the spring and the last to leave in the fall. Early and late spring dates are April 13, 1930 (M. W. Gardner), and May 12, 1929. Early and late fall dates are October 6, 1928 (D. R. Burtsfield), and October 27, 1929. There does not seem to be any material decrease in the numbers of these warblers in the past 40 years. Skins taken in the county are in our collection.

170. *Dendroica virens virens* (Gmelin). Black-throated Green Warbler. (667.) This very attractive little warbler is a fairly common spring and fall migrant but does not nest in the county. It is among the earliest of the warblers to arrive in the spring and is usually gone by the middle of May. In the fall most of them are gone by early October. Early and late spring dates are April 21, 1925, and May 24, 1929 (D. R. Burtsfield). Early and late fall dates are September 5, 1902 (Purdue Bird Club), and October 13, 1927. Skins taken in the county are in our collection. This warbler seems as common as formerly.

171. *Dendroica cerulea* (Wilson). Cerulean Warbler. (658.) This is a rather rare warbler in the county. It is usually seen during the spring migrations but may possibly nest as females have been taken as late as May 30 (1899), and this county is within its nesting range. This species is probably less common than formerly. An early date is April 24, 1897. Skins of specimens taken in the county are in our collection.

172. *Dendroica fusca* (Müller). Blackburnian Warbler. (662.) A common warbler especially during the spring migrations. Some seasons this species is very abundant and in others not common. It usually arrives early in May and leaves soon after the middle of the month. It

does not nest here. Early and late spring dates are April 29, 1893, and May 21, 1929. Fall dates are September 19, 1902 (Purdue Bird Club), and October 5, 1929, but the first arrivals probably reach here early in September. Skins of specimens taken in the county are in our collection.

173. *Dendroica dominica albilora* Ridgway. Sycamore Warbler. (663a.) Seemingly a rare species in the county as we have few records. There are no definite breeding records, but as the county is within the breeding range it seems that it should nest. Most of the records are for the latter part of April.

174. *Dendroica pennsylvanica* (Linnaeus). Chestnut-sided Warbler. (659.) This is a moderately common warbler during the spring migrations and less common in the fall. Its nesting grounds are farther north. It usually arrives early in May and is gone soon after the middle of the month. Early and late spring dates are April 27, 1892, and May 22, 1904 (Purdue Bird Club). Fall dates are September 5, 1902 (Purdue Bird Club), and October 5, 1929.

175. *Dendroica castanea* (Wilson). Bay-breasted Warbler. (660.) Usually the bay-breasted warbler is not common, but some years it seems to be quite so. It does not nest but is found as a migrant both spring and fall. In the spring these birds are found most commonly about the middle of May and in the fall in early October. Early and late spring dates are May 5, 1893, and May 25, 1929 (D. R. Burtsfield). The fall dates are October 2, 1929 (D. R. Burtsfield), and October 5, 1929. This species may have increased slightly in the past 30 years. Skins of this species taken in the county are in our collection.

176. *Dendroica striata* (Forster). Black-poll Warbler. 661.) Arriving rather later than the majority of the warblers the black-poll warbler is a not uncommon migrant but does not nest. It usually arrives about the middle of May and leaves toward the last of the month. Early and late spring dates are May 10 and May 28, 1902, both by the Purdue Bird Club. A fall date is September 30, 1931, although immature birds usually arrive earlier. Skins of this species taken in the county are in our collection.

177. *Dendroica pinus pinus* (Wilson). Northern Pine Warbler. (671.) This warbler is a regular but not very common migrant and does not seem to be quite as common as formerly. It does not nest but in the spring usually arrives fairly early. In the fall these birds arrive early in September and leave early in October. Early and late spring dates are April 27, 1892, and May 12, 1929 (M. W. Gardner). Early and late fall dates are September 5, 1902 (Purdue Bird Club), and October 5, 1929. Skins of this species taken in the county are in our collection.

178. *Dendroica palmarum palmarum* (Gmelin). Western Palm Warbler. (672.) This is one of our common migrating warblers, both in spring and fall. It arrives rather early, generally toward the last of

April, and has left by the middle of May. Early and late spring dates are April 24, 1897, and May 13, 1928 (M. W. Gardner). An early fall date is September 19, 1931, and a late one October 19, 1928 (D. R. Burtsfield). This warbler is easily recognized by the characteristic motion of its tail. Skins taken in the county are in our collection.

179. *Seiurus aurocapillus* (Linnaeus). Oven-bird. (674.) While a common migrant and summer resident, the oven-bird does not seem to be as common as formerly, decreasing somewhat as the thick woods, its favorite nesting habitat, gradually have been cut off. It is still fairly common, especially during the migrations, often coming into the yards in the towns. Oven-birds usually arrive early in May. Early and late spring dates are April 20, 1903 (Purdue Bird Club), and May 19, 1931. A fall date is September 30, 1929.

180. *Seiurus noveboracensis noveboracensis* (Gmelin). Northern Water-Thrush. (675.) The Northern Water-Thrush is a migrant both spring and fall. Apparently it is not common judging from the few records. It is not known to nest in the county. An early spring date is May 11, 1928, and a fall date is September 28, 1929 (D. R. Burtsfield).

181. *Seiurus motacilla* (Vieillot). Louisiana Water-Thrush. (676.) The Louisiana Water-Thrush is a fairly common migrant and less common summer resident in the county. Birds usually arrive fairly early in the spring and we have an extremely early date as March 28, 1903 (Purdue Bird Club). Most of our dates are for late April or May. They probably nest soon after arrival as a set of three eggs, taken May 25, 1893, is in our collection.

182. *Oporonis formosus* (Wilson). Kentucky Warbler. (677.) This species is a common migrant and not uncommon summer resident in the more heavily wooded sections where it was formerly quite common. It usually arrives early in May, but an unusually early date is April 24, 1927 (M. W. Gardner). Most or all of the birds are gone by late August. August 29 is a late date. A nest and set of four eggs taken June 11, 1891 are in our collection.

183. *Oporonis agilis* (Wilson). Connecticut Warbler. (678.) This apparently is one of our rarest warblers in Tippecanoe County as we have only one record. This is a sight record by D. R. Burtsfield, May 25, 1929.

184. *Oporonis philadelphia* (Wilson). Mourning Warbler. (679). The mourning warbler seems to be another rare species in Tippecanoe County and again we have but a single record, probably a sight record, May 28, 1904 (Purdue Bird Club).

185. *Geothlypis trichas brachidactyla* (Swainson). Northern Yellow-Throat. (681d.) This yellow-throat is a common migrant and summer resident throughout the county, preferring moist or swampy locations. It arrives usually in April and leaves in August or September. Early and late dates are April 22, 1903 (Purdue Bird Club) and Sep-

tember 21, 1902 (Purdue Bird Club). Skins of this species taken in the county are in our collection.

186. *Icteria virens virens* (Linnaeus). Yellow-Breasted Chat. (683.) The yellow-breasted chat is a migrant and summer resident, less common than formerly, since most of the dense thickets have been cut off. Its retiring habits make it seem less common than it really is. It is more often heard than seen. An early spring date is May 4, 1902 (Purdue Bird Club). Skins and eggs taken in this county are in our collection.

187. *Wilsonia pusilla pusilla* (Wilson). Wilson's Warbler. (685.) The beautiful Wilson's Warbler is a not very common migrant, perhaps less common than formerly, but can hardly be called rare. From our records it seems to be a spring migrant only, as we have no fall records. An early date is May 12, 1892, and a late date May 27, 1929. It seems to have been more common in 1929 than is usual. Skins of specimens taken in the county are in our collection.

188. *Wilsonia canadensis* (Linnaeus). Canada Warbler. (686.) The Canada warbler is another species which cannot be considered common though we have a number of records, all during the spring migrations. It does not nest in the county, and migration occurs about the middle of May. Our earliest date is May 10, 1927 (M. W. Gardner). A late date is May 25, 1929 (D. R. Burtsfield). Skins of specimens taken in the county are in our collection.

189. *Setophaga ruticilla* (Linnaeus). American Redstart. (687.) This beautiful warbler is a common migrant and summer resident in some numbers. It usually arrives late in April or early in May and begins nesting about the first of June. Our earliest date is April 24, 1904 (Purdue Bird Club). A late fall date is October 9, 1902 (Purdue Bird Club). This species has probably become slightly less common as the undergrowth has been cut off. Skins and eggs taken in the county are in our collection.

MEMBERS

Elected since the publication of volume 41

Amos, John Madison, 1711 South St., Lafayette.....M32
Bell, Dorothy M., 514 W. Jefferson St., Fort Wayne.....M32
Bjorklund, J. Harman, North Manchester.....M32
Black, Glenn A., 815 Oakland Ave., Indianapolis.....M33
Brubaker, Ralph, 1150 Portage Ave., South Bend.....M32
Buhl, Carl, 5846 N. Artesian Ave., Chicago, Ill.....M33
Carter, J. Cedric, R. R. 1, West Point.....M32
Cooper, Nelson, 1533 Leonard St., Indianapolis.....M32
Corley, Ralph Conner, Dept. of Chemistry, Purdue Univ., Lafayette..M32
Cortez, Samuel H., 1128 22nd St., Ogden, Utah.....M32
Cox, Ronald Clarence, R. R. 5, Box 565, South Bend.....M32
Crites, James Edward, Jr., 515 S. Washington St., Bloomington....M32
Duncan, Wilbur H., R. R. 3, Bloomington.....M32
Elliott, S. E., 4624 Rookwood Ave., Indianapolis.....M32
Grant, Major Chapman, Fort Benjamin Harrison.....M33
Harrell, Marshall Allen, R. R. 5, Bloomington.....M32
Harris, David Vernon, R. R. A, Bloomingdale.....M32
Haynes, James L., W. 17th St., Bloomington.....M32
Heaton, Robert R., Rushville.....M32
Herr, Helen, St. Mary's College, Notre Dame.....M32
Hunsaker, Frances, 509 S. Main St., Ann, Ill.....M32
Johnston, Robert Maurice, University of Notre Dame, Notre Dame..M32
de Landero, Pedro A., 1031 N. Niles Ave., South Bend.....M32
Lang, Maud Ora, R. R. 2, Box 37, Rockport.....M33
Lee, George H., Westfield.....M32
Leich, Carmen, 1106 S. Linwood Ave., Evansville.....M32
McConaha, Marjorie, Centerville.....M32
McIntire, Katherine, 3300 E. Jefferson Blvd., South Bend.....M32
McKee, Roy, 419 East South Dakota St.....M32
McMillan, Frances, St. Mary's College, Notre Dame.....M32
Maass, George H., 2522 S. Delaware St., Indianapolis.....M32
Neher, O. W., 1112 Home Ave., North Manchester.....M32
Northwestern University, Dept. of Geology and Geography, Evanston, Ill. M32
Rogers, Roy, North Madison.....M32
Romberger, Floyd T., Jr., 424 Littleton St., West Lafayette.....M32
Rothrock, David, 1000 Atwater Ave., Bloomington.....M32
Routien, John B., Montezuma.....M32
Russell, Merwyn A., 538 N. Sexton St., Rushville.....M32
Scherer, Rhodes K., 1841 E. Virginia St., Evansville.....M32
Spahr, Raymond John, 115 N. St. Louis Blvd., South Bend.....M32
Tarvin, Noble R., 222 Wiggins St., West Lafayette.....M32

Toussaint, Joseph A., 405 Badin Hall, Notre Dame.....M32
Trexler, Philip C., R. R. 5, Box 500, South Bend.....M32
Trippel, Albert W., 221 W. Sixth St., Mishawaka.....M32
VonOsinski, Wm. Philip, 1405 Jefferson Ave., LaPorte.....M32
Walton, Milford T., R. R. 3, Loogootee.....M32
Whelan, Mary, 225 First St., Weston, W. Va.....M32
Wimple, Margaret Louise, 109 Main St., Ligonier.....M32
Wood, Morris Wistar, Culver Military Academy, Culver.....M32
Zimmerman, Helen R., 348 State St., West Lafayette.....M32

JUNIOR ACADEMY OF SCIENCE

Bloomington Junior High School General Science Club. Charter member. 1931. Bloomington.

Crawfordsville High School Audubon Society. Charter member. 1931. Crawfordsville.

Crispus Attucks High School Biology Club. Charter member. 1931. Indianapolis.

Fort Wayne North Side High School Geography Council. Elected May 20, 1932. Fort Wayne.

North Madison High School Hilltop Nature Study Club. Charter member. 1931. North Madison.

Shortridge High School Chemistry Club. Charter member. 1931. Indianapolis.

Technical High School Nature Study Club. Elected 1932. Indianapolis.

Valparaiso High School Sciemus Club. Charter member. 1931. Valparaiso.

West Lafayette High School Science Club. Elected 1933. West Lafayette.

Whitley County Indiana Junior Academy of Science. Elected 1933. Columbia City.